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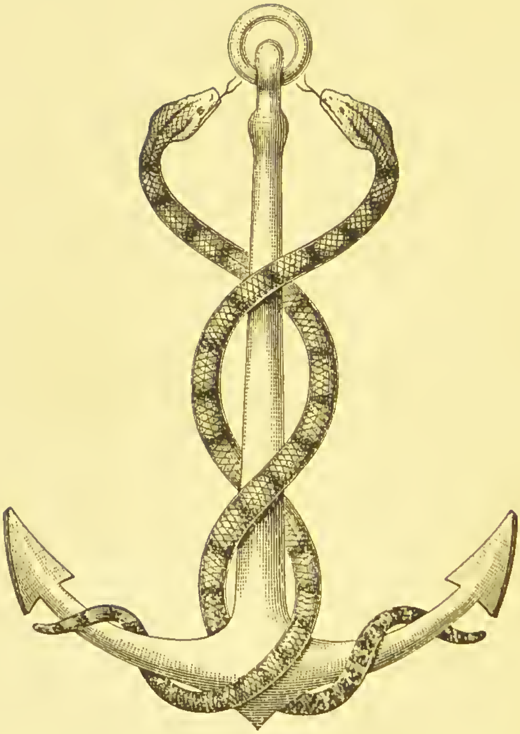

NUNQUAM ALIUD NATURA, ALIUD SAPIENTIA DICIT.

ASEPTIC SURGERY

BY

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TO

THOSE WITH WHOM I HAVE THE GOOD FORTUNE AND HAPPINESS TO WORK, IN ACKNOWLEDGMENT OF THE DEVOTION WITH WHICH THEY DO THEIR DUTY.

PREFACE.

These notes upon Aseptic Surgery were written for the St. Bartholomew's Hospital Journal. Since they began my friends and pupils have frequently requested me to republish them. I now have much pleasure in complying, and, in doing so, trust they will be increasingly useful in their new form. The notes naturally fall under four headings:—*First*, the principles upon which aseptic surgery is founded, including a short account of the commoner bacteria; *Second*, the distribution of bacteria, with special reference to surgery; *Third*, the means at our disposal for destroying bacteria, and for preventing their growth; and *Fourth*, a brief account of the way in which we apply the foregoing to surgical practice, and some of the results.

C. B. LOCKWOOD.

19 Upper Berkeley Street,
Portman Square, W., *January* 1896.

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PART I.

will, therefore, be dealt with as simply and briefly as possible; and in doing so I will try and make clear the reasons upon which the various details are based. It is quite impossible to practise aseptic surgery with success, unless not only the surgeon and his assistant but also the sisters and nurses, have a clear and distinct knowledge of its principles. Moreover, they must all possess a firm conviction of the truth of those principles.

This conviction does not grow in a day, but comes gradually, as we see that aseptic surgery is founded upon reason, is capable of proof, and gives the results which were promised.

Definitions.

Before we discuss the two great principles of aseptic surgery, the meaning of certain words which must often be used ought to be defined. First, I refer to the words "septic" and "aseptic," and it will be seen that both here and elsewhere various references will be given to what others have written. Those who wish to dip deeper into this subject and to know it better, are advised to consult these authorities themselves, and not to take them at second-hand.

There can be no doubt but that the word "septic"

had originally its literal meaning and was applied to wounds which had the odour of putrefaction (σήπειν: *to make rotten* or *putrid*). This was evidently the sense in which it was used by the authors of the Pathological Society's Report upon septicæmia and pyæmia in 1879,[1] and by all the earlier writers upon surgery. Further, it was a matter of common observation that these septic wounds were prone to be associated with septicæmia, pyæmia, erysipelas, hospital gangrene, and so forth. In consequence, these diseases were often referred to as septic diseases, because they occurred when wounds became putrid.

Cases were observed, however, in which septicæmia or pyæmia occurred without any decomposition of the fluids in contact with the wound.[2] The discovery of more exact methods, especially Koch's invaluable method of cultivating bacteria upon solid nutrient media,[3] such as gelatin, or agar-agar,[4] explained this mystery, and showed that many of the bacteria of

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[1] *Trans. Path. Soc.*, London, vol. xxx. p. 1, *et seq.*

[2] "Pathological Society's Report," p. 29.

[3] "Mittheilungen a. d. Kaiserlichen Gesundheitsamte," vol. i., 1881, p. 18. Translated by Victor Horsley, for *New Sydenham Soc.*, 1886.

[4] The gelatin is the same kind as that which is used for making the ordinary jelly which is served at table. It melts at about 25° C., or a temperature a little higher than summer heat. Agar-agar is a firmer kind of gelatin, which bears a much higher temperature, and melts at about 50° C.

septicæmia and pyæmia caused no odour of putrefaction.

On the other hand, many of these bacteria reveal their presence by causing inflammation and suppuration, so that pus became an important indication. At the present time I believe it is correct to say that most surgeons would call a pus-producing wound "septic," quite apart from the occurrence of a putrid odour.

Used in this way, it is clear that the word "septic" has been divorced from its original meaning, and implies that the wound is infected with pyogenic bacteria, which, it is to be remembered, are also capable of causing pyæmia, septicæmia, and other grave affections. Pus is, however, rather a crude test of wound infection. I have often, by means of culture experiments, ascertained the presence of bacteria, such as staphylococcus aureus or streptococcus pyogenes, in wounds many hours before any pus appeared. There are some who hardly recognise pus unless considerable quantities are present. Those who are accustomed to inoculate culture media from the wounds which they have treated, know that the slightest moisture is a highly suspicious circumstance, and nearly always implies infection.

There is yet another class of wounds which is infected with various kinds of bacteria derived from

the patients' skin. In some of these the suppuration is so slight that it is often ignored; in others it is absent. The pathogenic properties of these skin bacteria are almost unknown, so that provisionally it is wise to class them with the other pyogenic bacteria, and call the wounds in which they occur septic. It will be easy, when our knowledge permits, to give more definite names to wounds of this kind.

Thus the word "septic" always implies the presence of bacteria; but not necessarily the presence of those of putrefaction, or even those of suppuration. I have been asked whether I should call a wound which contained tubercle bacilli "septic." No; I should call it "tubercular," thus placing it in its proper class. It might, of course, be—and usually is—septic as well as tubercular. In truth, it may be imagined that, as our knowledge grows, wounds which are now called septic will gradually fall into other classes. This, however, in no way affects the principles of our wound treatment, which, as will be seen, aims at the absolute exclusion of all bacteria, quite irrespective of their supposed properties.

In the following notes the term aseptic will be applied to wounds or things which contain no bacteria, or, in other words, which are sterile; also any method of wound treatment which aims at sterility will be

called aseptic. This is slightly different from the sense in which the word is used by some surgeons. For instance, in a popular French text-book[1] three methods of wound treatment are described: the aseptic, which aims at sterility by the use of dry or moist heat for all instruments, dressings, or materials; the antiseptic, which aims at attaining the same end by the use of chemicals; and, lastly, the mixed method, in which both of the preceding are used. It will be seen later that the mixed method is the one which I am in the habit of using, but with an abiding faith in the efficacy of heat, and a profound scepticism as to the power of chemicals. Thus the word aseptic has undergone some evolution since, in 1882, Watson Cheyne wrote that the method "introduced by Mr. Lister . . . attains the ideal of results, viz., a complete absence of putrefaction—an asepsis. His method, then, is best designated by the term expressing its results—Aseptic."[2]

With regard to two other words which are also in constant use—namely, "antiseptic" and "disinfectant," it is customary to say that an *antiseptic* is that which prevents or retards the growth of bacteria, and a *dis-*

[1] Jamain, "Manuel de petite chirurgie," 7e éd., par Terrier et Péraire, 1893.

[2] "Antiseptic Surgery." W. Watson Cheyne. 1882. Page 51, foot-note.

infectant is that which kills them outright. In this sense an antiseptic would be useless as a disinfectant, although a chemical disinfectant might, when diluted, become an antiseptic. All this may seem rather casuistical and complicated, but the differences must be mastered, otherwise antiseptics will be used under the impression that they are disinfectants. I can adduce an instance in which my ignorance of the fact that I was only using an antiseptic, when I ought to have used a disinfectant, probably cost the unfortunate patient her life.

Principles of Aseptic Surgery.

The two great principles upon which aseptic surgery is founded are, as I have stated elsewhere[1]: (1) That the healthy unexposed tissues are sterile; (2) That suppuration and the other septic diseases of wounds are due to microbes introduced from without. It would require volumes to narrate the facts upon which these two inductions are based. Each one must convince himself or herself of these truths by study, and, if possible, by experiment. Everyone ought to read, at least,

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[1] See three reports on Aseptic and Septic Surgical Cases, *Brit. Med. Journ.*, London, 25th October 1890, 28th May 1892, and 27th January 1894.

the writings of our greatest surgeon, Sir Joseph Lister,[1] and the lucid experiments of the late Professor Tyndall.[2] The work of the last scientist is a sure foundation upon which to build.

Sterility of Healthy Tissues and Organs.

Asepsis would be impossible were it not that the healthy unexposed tissues and organs are sterile. This has been ascertained by the convincing experiments of Lister, Pasteur, Tyndall, and others,[3] and is confirmed every moment by the results of surgical practice. Investigations show that bacteria are absent from the blood and from the various organs—from the kidneys, ureters, bladder, and urethra, and from the urine of healthy individuals; from the liver, gall bladder, and biliary ducts, and from the bile; from the salivary glands, and the saliva in their ducts; from the acini of the lungs and smaller bronchioles, and from the expired air, provided it is not mixed with the secretions

[1] I have daily reason to deplore that the epoch-making writings of Sir Joseph Lister have not been collected and published in a single work, as has just been done for the late Sir William Bowman.

[2] "Essays on the Floating-matter of the air in relation to Putrefaction and Infection," London, 1881.

[3] Hauser, in an able monograph ("Ueber das Vorkommen von Mikroorganismen im lebenden Gewebe gesunder Thiere," *Arch. f. exper. Path. u. Pharmakol.*, Leipzig, 1886, bd. xx., p. 162), gives many references to the literature of this important subject.

of the mouth or air passages; they are also absent from the mammary gland, and from the milk in its ducts, and from other organs and secretions which it is unnecessary to specify. The entrances into the various ducts and passages are, however, exceptions to these rules; so that, to obtain the various secretions uncontaminated with bacteria, stringent precautions are required.

The absence of bacteria from the various tissues, organs, and fluids may be ascertained by direct observation. Bacteria cannot be seen in any of them so long as they are obtained from healthy individuals. Improvements in microscopical methods only serve to establish this statement upon a surer basis. It is obvious, however, that such minute objects as bacteria might elude the most patient and skilful search.

But experiments fully substantiate the results of direct observation. Portions of organs or tissues may be kept under a protecting shade or in nutrient media for indefinite periods without any change occurring. I have before me a piece of fat which was removed from the healthy living body more than two years ago. It has floated in nutrient broth all this time without any change at a temperature the most favourable for the growth of bacteria. The fat looks as fresh and yellow

as the day of its removal from the body, and the broth as clear as when it was made. In other tubes of nutrient fluid are portions of subcutaneous tissue of fascia, of muscle, and of peritoneum, all of which have behaved the same. Had any of the ordinary bacteria been present in these tissues, decomposition would inevitably have ensued. It has been abundantly proved, by the experiments of Pasteur, Lister, Tyndall, and others, that the decomposition of dead organic substances is caused by bacteria. The slight chemical changes which sterile dead organic substances undergo owing to the slow conversion of albumen and fat into other compounds, and owing to crystallisation, need not be taken into account. By some observers whole organs have been preserved entire by simply protecting them from bacterial contamination. Furthermore, it is now a matter of everyday knowledge that milk, vegetables, fruit, and meats of various kinds can be preserved almost indefinitely by destroying the bacteria which may have got into them, and by afterwards protecting them from fresh contamination. Anyone who has worked at experimental pathology soon becomes convinced of the truth of this great induction. Not only can he grow nothing from healthy tissues, but after successful inoculation with pure cultures of anthrax, tubercle, staphylococcus aureus, or strepto-

coccus pyogenes, and so forth, he finds in the tissues the organism he placed there, and none other.

For the success of experiments such as I have mentioned, much depends upon the skill and accuracy of the experimenter, and upon the ease with which the organ can be removed from the body. Some are more easily contaminated than others, and it is particularly difficult to succeed with very hairy animals. Here again, as the knowledge and skill of experimenters grow, better and more certain results are obtained, and the sterility of the healthy tissues and organs becomes more fully substantiated. The controversy which has raged around this most important subject, reminds one of that which was waged over the theory of spontaneous generation; and there is no doubt but that it is ending in the victory of those who believe in the sterility of the healthy, living tissues. Mark the word *healthy!* It is not at all improbable but that there are conditions of the body, rare, indeed, and ill understood, in which clouds, as it were, of bacteria pass through the circulation. If there be no determining influence, these escape from the body, or are killed within it, without doing any harm. A bruise, a wound, or other *locus minoris resistentiæ* is, however, sufficient to arrest their course and enable them to cause suppuration or other diseases. As I proceed, evidence will be

brought in support of this hypothesis; but at present I merely wish to draw attention to the importance of the qualification "healthy." Later it will be seen how careful we are to avoid any operations, except those of strict necessity, upon patients who are not in perfect health.

Putrefaction.

Under ordinary circumstances death is followed by decomposition with such certainty that it is hard to think of these changes apart from one another. It is most important, however, to realise that decomposition does not follow in the footsteps of death, whether it be of the whole body or of a part, unless bacteria are present and able to act. But bacteria are so universal that they attack all dead tissues which are suitable food for them, unless their action is prevented. The bacteria of putrefaction are so universal that their absence from normal dead tissues may be taken as indicative of the absence of other kinds. I use the words normal tissues, to exclude such as contain tubercle, actinomyces, and other organisms of the same kind.

Putrefaction of albuminous materials was originally thought to be due to a microbe which was called by Cohn the bacterium termo. Hauser[1] differentiated

[1] "Ueber Fäulnissbacterien und deren Beziehungen zur Septicæmie." Leipzig, 1885. P. 12, *et seq.*

the bacterium termo into three species, which he named proteus vulgaris, proteus mirabilis, and proteus Zenkeri. He says that these bacteria cause decomposition of wound secretions, mortification of tissues, and toxic phenomena of greater or less severity.[1] They are pathogenic for rabbits and guinea pigs. Hauser gave rather massive subcutaneous injections, and produced inflammation, œdema, suppuration, and necrosis. After death the internal organs showed no signs of disease, but proteus vulgaris was recovered in pure culture from the peritoneal effusion of a guinea pig. Cultures of proteus vulgaris and of proteus mirabilis which had been sterilised by filtration caused a rapidly fatal result when injected into the venous system (a true sapræmia). Two facts seem to stand out from Hauser's work, namely, that he used very large doses of his cultures, and that no alterations were seen in the internal organs. An examination of the blood and of the tissues by modern bacteriological methods does not seem to have been made.

Methods of Investigation.

To test the sterility of small organs, tissues, bits of skin, sponges, towels, silk, fluids, discharges, or sub-

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[1] *Loc. cit.*, p. 76, *et seq.*

stances from wounds, or other materials, transparent fluid culture media are most convenient and speedy. They are more easily prepared than the transparent solid media, and, I believe, give more reliable results. The following are the ingredients of Hueppe's broth, which is one of the more easily made kinds[1]:—Boiled water, 1 litre; peptone powder, 5 grammes; grape or cane sugar, 5 grammes; extract of meat, 30 grammes. These are to be mixed together in a glass beaker (with a cover to prevent the unnecessary entrance of dust) and boiled over a gas burner or spirit lamp. Whilst boiling, the mixture should be neutralised with a few drops of a solution of carbonate of soda. This should be added until the litmus paper begins to turn blue. After having been boiled for a quarter of an hour, the fluid should be filtered until quite clear, and then decanted into clean and sterile test tubes, until they are filled for about two inches of their depth. These are then plugged with sterilised cotton wool, which prevents the entrance of bacteria, and the whole sterilised by steaming for half an hour upon, at least, four consecutive days. The first boiling kills the cocci and bacilli, the subsequent ones kill the several swarms of bacilli which have germinated from spores, before they have time to

[1] Klein, "Micro-organisms and Disease," third edition, 1886, gives explicit directions for preparing culture media.

develop fresh spores. The sterility of these tubes ought to be tested by keeping them for a few days in an incubator at the temperature of the human body.

Culture Media.

The transparent solid culture media are troublesome to make, and can now be obtained without difficulty from a number of manufacturers. Goffi, Dr. Klein's laboratory assistant, is good enough to supply me with all the media I require. They are required for the correct diagnosis of the kinds of bacteria which may have grown in the broth.[1] Roughly speaking, broth will tell in twenty-four or forty-eight hours whether anything is septic. It is, however, necessary to wait much longer before it is safe to assert that anything is aseptic. Sometimes so few bacteria are present in the substance which is being tested that some days are required for their multiplication.

The culture tube of broth, gelatin, or agar-agar is used in the following way:—The assistant sterilises a pair of ordinary dressing forceps in the flame of a spirit lamp or Bunsen's burner; then he holds the mouth of

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[1] For the diagnosis of Bacteria, Eisenberg's "Bakteriologische Diagnostik," third edition, 1891, is almost indispensable. It has been translated into English.

the test tube which he is about to open, in the flame, until the projecting part of the wool plug, and all of its mouth, are thoroughly sterilised. Next, holding the test tube at a slight obliquity, to prevent dust and bacteria falling into it from the air, he rotates and withdraws the plug with the sterilised forceps, presents the tube to the operator, who puts the material into it with sterilised instruments, and, finally, disinfects the plug in the flame, and thrusts it back into the test tube. The tube is then placed in an incubator, which is usually kept at a temperature of 75° F. (summer temperature). The various departments at St. Bartholomew's now contain incubators, so that anyone can practise for himself. But those who are not near such accommodation will find one of Hearson's incubators easy to manage, and reliable. Some sorts of bacteria will grow in a warm room, and I should think a conservatory or greenhouse would be a good place, if an incubator could not be obtained. Everyone ought to do some experiments of this kind. At first the experimenter will be humiliated by his failures, but afterwards his standard of perfection will be extraordinarily raised. Everyone, too, who has the opportunity ought to attend Dr. Kanthack's lectures and demonstrations upon bacteriology. Such knowledge as he imparts is as important in surgery as anatomy, physiology, and pathology.

CHAPTER II.

BACTERIA THE CAUSE OF THE DISEASES OF WOUNDS.

In the last Chapter I tried to show that the first induction upon which aseptic surgery is founded ought to be mastered and believed.

This is easier than to master and believe the second, which says that suppuration, erysipelas, pyæmia, septicæmia, and other diseases of wounds are caused by bacteria introduced from without. The acceptance of this involves great responsibility, because it can, I think, be shown that even with our present means bacteria may be excluded from wounds, provided the means are used by those who hold the tenets of aseptic surgery and have been trained in its methods. Much remains to be done to perfect and simplify methods, and the practice of the future will doubtless be much more simple and certain than that of to-day.

It also follows that we must, with Grawitz and de Bary, repudiate the old theory that suppuration[1] may be

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[1] The effects of strong chemicals upon the tissues is discussed in Chapter XI., p. 115.

caused by thermal, mechanical, chemical, or electrical irritants. Thus, in the absence of bacteria, a foreign body, a tight stitch, a ligature, or tension of any kind cannot produce a drop of pus.

Micrococci.

The bacteria found in wounds are usually micrococci and bacilli. As I am not writing for accomplished bacteriologists or finished surgeons, it may not be out of place to enter into a few details about these. The micrococci are spherical cells which multiply by fission, and always produce spherical cells. Each micrococcus consists of a delicate capsule filled with microprotein. When in the process of fission two micrococci adhere to one another, they form a *diplococcus.* When micrococci grow in chains, they form *streptococci;* and when in clusters, *staphylococci.* Micrococci resist heat for some time, and are most difficult to kill with chemicals.

Bacilli.

The bacilli are bodies of which the length is greater than the breadth. The length may just exceed, or be twice, thrice, or many times as great as the breadth. They resemble micrococci in possessing a cell membrane

and microprotein contents, and some kinds have, in addition, one or more spores. Some have delicate lashes or flagella, by which they propel themselves through the fluids which they inhabit. Bacilli multiply by fission and by spores. In the former process a single rod divides into two, which may remain adherent by their ends (diplobacillus), or by a continuance of the process of growth and fission a long thread (leptothrix) may result.

Spores.

The spores are minute oval or spherical cells, which appear as clear shining spots in the substance of bacilli. They serve to perpetuate the species, and after having been quiescent for years may, when placed under favourable conditions of warmth, moisture, and of nutriment, sprout and give birth to bacilli the same as those from which they themselves sprung.

Vitality of Spores.

Spores are endowed with extraordinary tenacity of life. They resist for long periods considerable degrees of heat and cold, or the action of strong chemicals. In addition to their cell wall, both cocci and bacilli possess a covering of an albuminous substance, often mingled with

fat (Macé). When this is coagulated by chemicals it adds greatly to the resisting power of the organism.

Multiplication of Bacteria.

The prodigious rapidity with which bacteria multiply is shown by Macé's calculation. According to Cohn it took two hours for two bacilli to complete their fission into four. Calculating upon this basis, Macé says that in three days these would have produced four thousand seven hundred and seventy-two billions. To reassure us he adds that happily for man this prodigious fecundity is continually checked.

Physiology of Bacteria.

The various bacteria, in addition to warmth, moisture, and nutriment, require oxygen. Some flourish in the presence of free oxygen (aërobes), others (anærobes) will not grow in the presence of oxygen. The latter are cultivated by bacteriologists in an atmosphere of hydrogen or nitrogen, or in sealed capsules. It is hard to imagine that a living thing can exist without oxygen, and it is almost certain that anærobes obtain theirs from the substances in which they live. Finally, many bacteria live indifferently in either the presence or

absence of free oxygen. It is simplest to call these *indifferent.* As bacteria grow they manufacture or excrete substances which are called ptomaines or toxines. Some of these are the most potent poisons known, and are comparable to morphine, atropine, strychnine, and muscarine. When Koch's treatment of tubercle by the injection of toxines manufactured by the tubercle bacillus (tuberculin) was in vogue, it was most striking to see an almost inappreciable dose send the temperature up to 105° F., cause erythematous rashes similar to a violent outburst of erysipelas, and in some instances almost kill the patient. Bacteria also act as ferments, and produce poisons by causing chemical changes in the substances in which they live.

Requirements of Henle and Koch.

At the outset of any inquiry into the truth of the second induction it is necessary to have a clear conception of what is meant when we say that bacteria are the cause of suppuration, erysipelas, pyæmia, septicæmia, or of any other disease.

Henle clearly pointed out, and Koch[1] emphasised the

[1] "Microparasites in Disease," *New Sydenham Soc.*; Koch, "The Etiology of Tuberculosis," translated by Stanley Boyd.

requirements which must be fulfilled before any bacterium can be said to be the cause of a disease. First, it must be found in the blood or lymph or tissues of the diseased animal or human being; second, it must be separated and grown for many generations outside the body; third, the pure cultivation must, when introduced into the healthy living body, produce the disease in question; fourth, the same bacterium must be found in the body of the animal experimented upon, and be capable of further growth and transmission.[1]

These conditions have been fulfilled by many of the bacteria which are found in septic wounds; as examples may be cited *staphylococcus pyogenes aureus, staphylococcus pyogenes albus, streptococcus pyogenes, streptococcus erysipelatosus, bacillus septicus, bacillus coli communis, tetanus bacillus, tubercle bacillus, anthrax bacillus,* and several others. Septic wounds, however, contain many bacteria the properties of which are still uncertain. Some are pathogenic; others, perhaps, are non-pathogenic. But definite knowledge upon this point is not essential, because aseptic surgery aims at the exclusion of every kind, quite irrespective of their properties. No surgeon could, on this account, discard bacteriology.

[1] Crookshank, "Manual of Bacteriology," second edition, 1887, p. 2; see also "Bacteria and their Products," by G. Sims Woodhead. 1892.

Many diseases are caused by bacteria and can only be explained and understood with the help of knowledge gained in the bacteriological laboratory. Moreover, a knowledge of bacteriology is required for the scientific use of antiseptics and disinfectants. Therefore I propose now to give some further details about some of the wound bacteria which have fulfilled the requirements of Henle and Koch. *Staphylococcus pyogenes aureus* comes first because it is, perhaps, found oftener than any other in acute suppurations and septic wounds. It has been proved to be the cause of a number of surgical diseases, amongst which may be mentioned acute suppurative periostitis, acute osteomyelitis, acute suppurative peritonitis, inflammatory wound gangrene, septicæmia, and pyæmia.

Eiselsberg[1] examined eighteen cases of acute suppuration to ascertain what bacteria were present. In eight, *staphylococcus aureus* was found; in four, *staphylococcus aureus* and *streptococcus pyogenes;* in three, *staphylococcus aureus* and *albus,* and *streptococcus pyogenes;* in two, *streptococcus pyogenes;* and in one, *staphylococcus aureus, staphylococcus albus, streptococcus pyogenes,* and a bacillus.

Bossowski,[2] who investigated Professor Mikulicz's

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[1] *Wien. med. Wchnschr.*, 1886, p. 133.

[2] "Vorkommen von Mikroorganismen in Operations-Wunden unter dem antiseptischen Verbande," *Wien. med. Wchnschr.*, 1887, p. 258.

surgical cases by Koch's method of plate culture, found that the secretions of ten wounds out of fifty were sterile. Of the forty septic cases twenty-six contained *staphylococcus albus*, but in eleven of these *albus* was mixed with other bacteria ; nine contained *staphylococcus aureus*, three being mixed. The rest contained bacilli or other kinds of micrococci. These septic cases usually suppurated ; the sterile were healed by first intention. In examining wounds by culture methods I have found that much depends upon the degree of success with which asepsis is approached. Of late when asepsis has failed I have seldom found anything but skin bacteria in the wounds which I have examined. Micrococci are often found in the vicinity of wounds which have healed by first intention. As a rule the presence of bacilli indicates grave faults in technique. This applies especially to the putrefactive bacilli. I now refrain from giving an opinion as to the bacteria in wounds, unless they have been investigated by plate cultures. This often reveals bacilli which were quite unsuspected ; having been obscured by the more rapidly growing micrococci.

Plate Cultures.

The method of plate culture is of extreme importance, and as a means of investigation is often neglected.

Statements made by those who do not use it are to be received with caution. Its principles are very simple. A minute particle of the suspected material is shaken up with half a test tube full of sterilised distilled water. With a particle of this a liquefied gelatin or agar-agar tube is inoculated, poured into a shallow glass dish protected with a glass cover, and left to re-solidify in a wide-spread, thin layer. After a few days in the incubator the sparsely scattered bacteria begin to grow in separate and distinct colonies, from which pure cultures of the different species are easily started.

CHAPTER III.

MICROCOCCI OF WOUNDS.

Staphylococcus Pyogenes Aureus.

I now propose to describe the bacteria found in septic wounds a little more fully, beginning with the micrococci. This will enable us to understand more clearly their evil effects.

Staphylococcus pyogenes aureus is spherical. Its diameter is about 1 μ, but smaller or larger specimens are often met with, and cultures sometimes contain large cocci which stain badly.[1] Doubtless the size of the cocci depends upon their age, their nutriment, the conditions under which they were grown, and upon the way in which the specimen was prepared for examination. The amount of heat used in drying has an obvious effect. The cocci also look smaller in sections of tissues.

Staphylococcus pyogenes aureus grows in dense clusters like bunches of grapes, and with great rapidity, upon

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[1] Cornil et Babes, "Les Bactéries," third edition, tome i., p. 403, Fig. 159; also Macé, "Traité pratique de Bactériologie," Paris, 1891, second edition, p. 265. Both of these books are most useful for reference.

all kinds of nutrient media. Gelatine, agar-agar, and sterilised potato are the most convenient. It grows upon the surface and in the depths of the gelatine, being indifferent. On the surface it looks like a layer of gold dust, and justifies its name *aureus.* At first the colour may be pale, almost white, but in twenty-four or forty-eight hours the golden tinge appears. Thus it is hazardous to pronounce too quickly upon the nature of a young culture. The pigment which is produced has a tendency to diffuse and stain the medium upon which the cocci are growing. This is best seen in agar-agar and potato cultures. The formation of this pigment has been supposed by some to account for the jaundiced hue which is seen in some cases of pyæmia. The pigmentation of cultures is deepest on the surface, and free oxygen is necessary for its proper production.[1] *Staphylococcus aureus* liquefies gelatine or solidified blood serum with great rapidity. They are, I believe, peptonised by the microbe, which doubtless acts in the same way upon unorganised blood clots within the body.

Staphylococcus aureus has an odour of pus when growing upon culture media.

The pathogenic properties of *aureus* have been abun-

[1] Flügge, "Micro-organisms with special reference to the Etiology of the Infective Diseases," *New Sydenham Soc.*, trans. by W. Watson Cheyne, 1890, p. 185.

dantly proved. Self-sacrificing experimenters have caused acute suppuration in themselves with pure cultures. Garré rubbed one which had been obtained from a case of osteomyelitis into the skin of his arm. The result was a crop of furuncles, which occurred wherever the microbe had entered the cutaneous glands.[1] But to cause suppuration quickly with cultures of *staphylococcus aureus*, it is usually necessary to introduce them in considerable numbers. Small doses are, however, efficacious if a *locus minoris resistentiæ* has been made before the injection. Messrs. H. Waterhouse and Pridie found that a dilute solution of *staphylococcus aureus* could be injected into their cellular tissues without result. But if the part experimented upon had previously been constricted for three hours with a rubber ring, an abscess followed.[2]

Bumm also injected pure cultures of *staphylococcus pyogenes aureus* into the subcutaneous tissues of his own arm, and into the arms of two other persons. Acute abscesses developed in each case, and some of them

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[1] Flügge, "Micro-organisms with special reference to the Etiology of the Infective Diseases," *New Sydenham Soc.*, trans. by W. Watson Cheyne, 1890, p. 187.

[2] Herbert J. Waterhouse, "An Experimental Inquiry into the Influence of Certain Factors in the Causation of Peritonitis," Prize Thesis, Edinburgh, 1889. For an abstract of this excellent thesis see *Virchow's Archiv*, 1890.

became as large as a fist before they were opened. The pus contained *staphylococcus aureus*. Similar results have been obtained by Bockhardt.[1]

The experiments of Grawitz, Wegner, Waterhouse, Rinne, Fraenkel, and others show that small doses of *staphylococcus aureus* may be introduced without ill results into the cavity of the peritoneum. But suppurative peritonitis follows if the serous membrane be previously damaged by the drying due to exposure to air, by the action of chemicals, by tearing or laceration, or if foreign bodies or blood clots were present. The same results have been obtained with other bacteria, especially the *bacillus coli communis*. Obviously the above favourable conditions often occur in surgery.

I have at various times seen what power *staphylococcus aureus* has of causing suppuration and pyæmia, the first cousin of suppuration. In March 1890, I had a youth, aged fourteen years, under my care in the Great Northern Hospital. He was supposed to have had an attack of acute rheumatism. He came three weeks after its onset, with the usual signs of acute synovitis of the hip, very ill, with a temperature of 101° F. Some pus was removed with an aspirator from the neighbourhood of the hip-joint. In a few hours the culture media which had been inoculated with it contained *staphylococcus*

[1] Senn, "Surgical Bacteriology," Edinburgh, 1889, p. 85.

aureus. The hip was eut into, and the upper epiphysis of the femur found to be almost detaehed by acute suppuration at its junction with the shaft. Some of the eulture of *staphylococcus aurcus* was mixed with salt solution until the fluid looked milky. Six drops of this solution were injected into the auricular vein of a strong and healthy rabbit. In ten days the animal beeame paraplegic, and on the twelfth it was killed. It had suppuration around the lumbar part of its spinal cord, suppurative nephritis, and retention of urine. *Staphylococcus aurcus* was grown from the abscess round the cord, but the urine was sterile, probably because only the clear part of it, and not the turbid sediment, was used for inoculation. The kidneys contained quantities of micrococei. To make this case eomplete thc rabbit ought to have died of epiphysitis, but it is sufficient to note that the microbe caused a virulent suppuration, similar to that from which it came. But, as a matter of faet, *staphylococcus aurcus* has now been used so much by experimental pathologists that it is as well known as anthrax.

If a specimen of pyæmia was wanted for the bacteriology class I merely injected a solution of *aurcus* or of *strcptococcus pyogcncs* into a rabbit's veins, and felt almost sure of obtaining what was wanted.

Immunity—Natural and Acquired.

Too much stress is not to be laid upon inoculation experiments performed upon animals. The effects of bacteria are very variable. For instance, the bacillus of mouse septicæmia is fatal for house mice, whilst field mice are unhurt by it.[1] Anthrax kills European sheep, but is resisted by Algerian except in massive doses;[2] and *streptococcus pyogenes* seems to be most pathogenic for mankind, although, like others, I have had difficulty in producing with cultures of it disease in rabbits and guinea-pigs.[3] Anthrax is hardly at all pathogenic for dogs, although it kills sheep and cattle.[4] But the natural immunity which some animals enjoy can be abolished by suitable means. For instance, Pasteur found that fowls did not die of anthrax unless they were made ill, and their temperatures lowered by immersion in cold water. Frogs, on the other hand, were insusceptible to anthrax until they

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[1] Koch, "Traumatic Infective Diseases," *New Sydenham Soc.*, trans. by Watson Cheyne, 1880, p. 33.

[2] Chauveau, *Compt. rend. Acad. d. sc.*, Paris, 1879, tome lxxxix., p. 498.

[3] Rosenbach, "Micro-organisms in Human Traumatic Infective Diseases," *New Sydenham Soc.*, 1886, p. 408, translated by Watson Cheyne.

[4] See papers by Pasteur, translated by Dawson Williams, "Micro-parasites in Disease," *New Sydenham Soc.*, 1886. This is a most valuable volume, and contains several important monographs.

were kept in warm water. It is probable that similar influences affect the action of *staphylococcus aureus* and of other bacteria.

Many of the experiments which are narrated require to be accepted with caution. Owing to their close resemblance I have little doubt but that observers have hitherto failed to differentiate between some kinds of pathogenic and non-pathogenic cocci and bacilli. For instance, Bossowski[1] has described a micrococcus which has the closest resemblance to *staphylococcus aureus,* and which he calls *staphylococcus gilvus.* It liquefied gelatine more slowly than *aureus,* and was non-pathogenic for rabbits. It is said that the wounds in which it was found did not suppurate.

Under the name of *staphylococcus albus* many kinds of bacteria have doubtless been included. Welch[2] has described a micrococcus which is a constant inhabitant of the skin, and which he calls *staphylococcus epidermidis albus.* It bears the same relation to *staphylococcus albus* as *gilvus* does to *aureus.*

Independently of Welch I have myself[3] described

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[1] *Loc. cit.*, p. 256.

[2] "Conditions underlying the infection of Wounds," *Am. Journ. Med. Sc.*, Phila., November 1891.

[3] "Further Report on Aseptic and Septic Surgical Cases, with special reference to Infection from the Skin," *Brit. Med. Journ.*, London, 28th May 1892.

a *diplococcus cpidermidis albus* which is very like *staphylococcus pyogencs albus,* and was found in the vicinity of antiseptic wounds. I have very frequently met with it since, both in wounds and in broth into which skin has been dropped. I am by no means sure that it is the same as the *staphylococcus cpidermidis.* It produces a pcculiar odour as it grows, such as is smelt when uncleanly people remove their vestments. It seems to have no effect upon rabbits when injected into their blood, nor does it cause suppuration when squirted under the skin.

Staphylococcus pyogcnes albus, which has been referred to so often, has the closest resemblance to *staphylococcus aureus* in everything except colour. Grown upon culture media, however, it lacks the golden hue, and is white, as its name implies. Much remains to be done to clearly differentiate *staphylococcus albus* from the various bacteria which resemble it so closely in everything but its pathogenic propcrties.

CHAPTER IV.

MICROCOCCI OF WOUNDS.—*Continued.*

STREPTOCOCCUS PYOGENES.

Staphylococcus pyogenes aureus having been described, we may now proceed with an organism equally important, the *streptococcus pyogenes.* At the same time, the methods of staining which dressers or clerks ought to be able to practise without difficulty will be mentioned, also how to make cover glass preparations. These are so simple and satisfactory that it is to be hoped that every one may be incited to attempt them in future more often than at present.

The name *streptococcus* was given by Ogston to this species of coccus because of the chains in which it grows. In suitable media, such as sterilised broth, the chains attain their full dimensions, and in those of young and vigorous cultures I have counted upwards of two hundred cocci linked together in a tortuous chain. More commonly a chain contains from five to ten elements. The average size of the cocci is about 1 μ, but in the midst of the long chains some may be

seen which are twice as big, and which are called arthrospores. In the centre of some of the arthrospores I have seen small, round, shining bodies which appeared to be spores. I have never seen arthrospores in the *streptococci* in pus or in the tissues; only in those growing in culture media. When we come to disinfection, spores will be of great importance.

To obtain a pure culture of *streptococcus pyogenes* it is often sufficient to inoculate the pus of an acute inflammatory process into gelatine or broth. A case of cellulitis is the most favourable because, as Ogston long ago observed, the *streptococcus* is peculiarly associated with that condition. The finest chains which I have grown in broth came from a pelvic cellulitis. The growth on gelatine is very typical; no liquefaction occurs. An almost imperceptible growth advances over the surface. It consists of minute greyish white and almost transparent colonies, with abrupt and undulating edges. These colonies have hardly any tendency to spread, their growth soon ceases, and they remain about 1 mm. in diameter. Inoculated by puncture into the depths of the gelatine similar colonies appear, free oxygen not being essential for the growth of *streptococcus pyogenes.* In broth the *streptococcus pyogenes* grows with great luxuriance in delicate cloudy flakes, which deposit at the bottom and upon the

walls of the test tube. It also grows in agar-agar, sterilised milk, urine, and other nutrient media. It peptonises white of egg or meat when grown upon either of them in a vacuum.

Cultures of *streptococcus pyogenes* soon lose their virulence and die. After three weeks or a month they are useless for inoculation into most animals. Apparently the *streptococcus pyogenes* is most virulent in its action upon man. At the seat of inoculation it causes acute inflammation and suppuration, and has a marked tendency to invade the lymph paths and cellular tissue, causing lymphangitis, cellulitis, and erysipelatoid wound gangrene (Ogston). In these respects it differs from *staphylococcus aureus,* which is more prone to act locally and cause acute inflammation and suppuration, with sloughing and inflammatory wound gangrene. We might expcet that the *streptococcus* would insinuate itself more easily into lymph paths than *staphylococci,* which grow in dense immobile masses. When the *streptococcus pyogenes* in its journey along the lymphatics reaches the lymphatic glands it sets up suppurative adenitis. Far too often it enters the circulation and causes septicæmia and pyæmia. I have found *strepto-cocci* in incredible numbers in the walls of pyæmic abscesses and in their pus. They are also common in the renal infarcts which accompany pyæmia, and after

these infarcts have suppurated are found alive in urine. In Senn's summary of the work of Rosenbach, Pawlowsky, Besser, and Shüller, *streptococci* were found thirty-seven times in sixty-nine cases of pyæmia, *staphylococci* in twenty-three, both together in five, and *staphylococcus aureus* alone in four. The blood, pus and fluids of the tissues were examined.

The presence of *streptococci* in the urine is obviously of great diagnostic value, and very easy to ascertain. To find them it is only necessary to dry a drop of the urinary sediment upon a cover slip and stain it with carbol-fuchsin. It is a moot point whether an abscess in the kidneys always precedes the passage of bacteria. It is possible that other lesions may suffice, and perhaps the normal kidneys may, as Ogston and Cohnheim supposed, excrete bacteria. Sherrington has recently written a most valuable monograph upon this subject.[1]

At present the weight of evidence seems to be in favour of the view that their passage is always associated with some injury to the blood vessels or tubules of the kidneys.[2]

The urine gives early evidence of the entrance of bacteria into the circulation, but this valuable aid to

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[1] "Experiments on the Escape of Bacteria with the Secretions," *Journ. Path. and Bacteriol.*, Edin. and London, 1893, vol i., p. 258.

[2] C. S. Sherrington, *loc. cit.*

diagnosis is usually neglected. The urine which contains bacteria may betray nothing to the eye, and have the usual acid reaction. As a rule a faint cloud of albumen, such as is usually ascribed to pyrexia, is precipitated from it by heat. There is no difficulty in seeing the bacteria in cover glass preparations made from the sediment. By this method I have observed *strepto-coccus pyogenes* in the urine in pyæmia, *staphylococci* in severe cellulitis of the leg, and various cocci and bacilli in perforative peritonitis. Only a few hours is required after infection for the passage of the bacteria through the kidneys.

The kidneys of those who die of acute septic affections may appear normal to the naked eye, but the microscope usually reveals patches of acute disseminated nephritis such as are described by Ziegler.[1] Often small abscesses can be seen, and not infrequently infarcts. Sometimes I have by Gram's method found capillary bacterial emboli in kidneys which to the eye and ordinary histological methods seemed normal. The method invented by Czenzynke and used by Canon for demonstrating the influenza bacillus in blood is still more valuable, but rather complicated.

The bacteria in urine are often alive and capable of

[1] "A Text-book of Pathological Anatomy and Pathogenesis," translated by D. Macalister, 1886, Part II, p. 51.

being separated by plate cultures. They are few in number and probably attenuated. I have failed to cause suppuration in rabbits with subcutaneous injections of urine containing pyogenic cocci.

Rosenbach, von Eiselsberg,[1] Canon and others have found *streptococci* in the blood in cases of traumatic fever, pyæmia, and septicæmia. The blood may be obtained by pricking the finger after thorough disinfection. I have been accustomed to wash the finger with hot water and soap, scrub with a nail brush, soak with carbolic acid lotion 1—20, or perchloride of mercury lotion 1 in 1000, and remove them with absolute alcohol. Working at chronic pyæmia and hectic fever my results were always negative. Occasionally *staphylococcus albus* grew, but this is such a constant inhabitant of the skin that one felt distrustful. However, bacteria of any kind are exceedingly hard to find in chronic mycoses. Of late, Dr. Kanthack has been most successful in finding staphylococcus aureus, staphylococcus albus, and streptococcus pyogenes in acute mycoses, such as pyæmia and ulcerative endocarditis. The investigation of the blood is much neglected, even in cases in which it would be harmless and cause no distress.

[1] "Beiträge zur Lehre von den Mikroorganismen im Blute fiebernder Verletzer in geschlossenen Körperhöhlen, und in verschiedenen Sekreten," von Eiselsberg, *Wien. med. Wchnschr.*, 1886, p. 133. This paper gives a number of references.

The number of diseases in which *streptococci* have been seen is considerable. Amongst them are such closely allied conditions as erysipelas, cellulitis, abscess, peritonitis, pericarditis, endocarditis, puerperal fever, pelvic cellulitis, suppurative diseases of the ears and teeth, pyæmia, and septicæmia; also in pneumonia, scarlet fever, diphtheria, intestinal catarrh, acute disseminated nephritis, and in the diseases of some of the domestic animals,[1] particularly equine pneumonia. Of late it has frequently been found in acute suppurative periostitis (or acute necrosis). A few years ago the *staphylococcus aureus* was considered the sole cause of that disease, but now quite a number of pyogenic bacteria have been observed.

Sternberg says that Rosenbach in thirty-nine cases of acute pus formation found *streptococcus pyogenes* alone in fifteen, and associated with *staphylococci* in five. Passet, in thirty-three similar cases, obtained *streptococcus pyogenes* alone in eight, and associated with *staphylococci* in two.

Streptococci are often found in pyæmic arthritis and in suppurative arthritis. In the case of a youth who died of pyæmia following the amputation of his arm for a

[1] See an admirable paper by v. Lingelsheim, "Experimentelle Untersuchungen über morphologische, kulturelle, und pathogene Eigenschaften verschiedener Streptokokken," *Ztschr. f. Hyg.*, Leipzig, bd. x., 1891, p. 331, *et seq.*

printing machine accident, I found *streptococci* in the pus of the knee and ankle. At the same time his urine was full of *streptococci*. *Streptococci* were found in another case of acute arthritis of the knee. The joint had been infected from a suppuration about the upper epiphysis of the tibia. *Streptococci* were also found in the urine of an infant with endocarditis. The seat of inoculation was an ulcer near the anus.

In the fluid of septic meningitis caused by middle ear disease I found chains of cocci along with many kinds of bacilli. However, Kanthack's[1] work at this subject shows that *streptococcus* is rare in middle ear disease, whilst *staphylococcus aureus*, *staphylococcus albus*, *pneumococci*, and *bacilli* are common. The *streptococcus pyogenes* fulfils the requirements laid down by Henle and Koch. When young and virulent cultures are inoculated into the skin of the ears of rabbits it causes an erysipelatous blush, with suppuration at the point of inoculation. Injected into the cellular tissue, it often produces a diffuse suppurative inflammation, or, in other words, acute cellulitis. Injected into the joints or serous sacs, acute suppurative arthritis, or acute peritonitis or pericarditis, and so forth, are set up.

[1] "The Bacteriology of some Inflammatory Processes of the Middle Ear and Mastoid Cells," *Arch. Ophth. and Otol.*, N.Y., vol. xix., No. 1, 1890.

Injected into the blood stream, it often causes septicæmia or pyæmia. In these the smaller vessels are plugged with *streptococcus* emboli. If the animal lives long enough these end in abscesses. Hardened in spirit and stained by Gram's method, the organs which contain these emboli afford beautiful histological specimens.

Wyssokowitsch ascertained that if the aortic valves were injured before an intra-venous injection of *strepto-cocci* an acute endocarditis was the result. Rabbits are not easily killed with *streptococci*, but mice and guinea-pigs are very susceptible, and die rapidly after inocula-tion with minimal doses. My own observations tend to show that *streptococcus pyogenes* is most pathogenic for human beings, and especially for children; it is the cause of many of the fatal endings in cases of sepsis after operations. I am referring mainly to investigations made upon the tissues. It is to be remembered that *streptococci* are so easy to stain, and their chains are such striking objects, that they are not easily overlooked. An exaggerated idea of their frequency in diseased tissues might easily be acquired. Other organisms which are harder to stain, and which are less conspicuous, may oftentimes have escaped notice. Nevertheless in some of my cases these latter may have been the actual cause of the disease, the *streptococci* being mere accidental accompaniments.

VARIETIES OF STREPTOCOCCI.

Of late it has been endeavoured[1] to show that there are two main morphological groups of *streptococci*—namely, the *streptococcus longus* and *brevis.* These are characterised by the different lengths of their chains and by their action. *Streptococcus brevis* does no harm to animals, whilst *streptococcus longus* is deadly for mice, and kills rabbits and guinea-pigs. Perhaps I may add that the short chain variety makes the broth in which it is grown turbid, but the long chain leaves it clear. Further, the latter is said to grow invisibly upon potato. Welch[2] has been unable to confirm these observations.

Perhaps the separation of the *streptococci* into *longus* and *brevis* is artificial. I have myself often observed that the luxuriance of the chains depended upon the media and the age of the cultures. They were short in gelatine and agar-agar, but long in broth. In old cultures, too, the chains seemed to be broken up into short pieces.

There is experimental ground for supposing that human beings[3] and animals can be protected against

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[1] Lingelsheim, *loc. cit.*

[2] "Conditions underlying the Infection of Wounds," *Am. Journ. Med. Sc.*, Phila., November 1891.

[3] "Puerperal Septicæmia: Use of Streptococcus Antitoxin," A. E. Kennedy, *Lancet*, 2nd November 1895, p. 1106.

the action of virulent *streptococcus longus.* This has been accomplished by injecting them with the blood of animals which had themselves been rendered immune by repeated inoculations with attenuated cultures of *streptococci.*[1] It was in a manner similar to this that Tizzoni and Cattani produced immunity against the bacillus of tetanus.[2] Remembering how often *streptococci* cause traumatic infection, these observations throw an interesting light upon the safety of anatomists and pathologists from pyæmia and septicæmia.[3] They also help to explain the rapid healing which occurs after amputations for prolonged suppurative arthritis.

A fact of some importance bears upon the general identity of the *streptococci* found in a diversity of diseased conditions. It has been found that an animal which has been rendered immune against the *streptococcus* which is most virulent for it is also protected against all other kinds.[4] Now *streptococci* are so fatal for mice that this is a very remarkable achievement, scarcely less noteworthy, as Behring says, than the protection of guinea-pigs against diphtheria. The pro-

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1 "Untersuchungsergebnisse betreffendden Streptococcus longus." *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, Behring, bd. xii., 1892, p. 195.

2 *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, bd. ix., p. 189 *et seq.*

3 Sir James Paget, "Clinical Lectures and Essays," 1875, p. 323.

4 Behring, *loc. cit.*, p. 195.

tection of horses against *streptococcus pneumoniæ* would be of great economic value if it became an established fact. Military horses are very prone to that disease.

The *streptococcus* of erysipelas resembles that of suppuration so closely in appearance and growth, in media, and possibly in effects, that Cornil and Babes, Sternberg, and others, think they are identical. Like the *streptococcus pyogenes*, the *streptococcus* of erysipelas grows along the lymph paths, and affects the lymphatic glands. It also causes suppuration when introduced into cellular tissues. In a case of death from erysipelas I found *streptococci* in the heart's blood. The *streptococcus* of erysipelas is found best at the margin where the redness is spreading; it also occurs in the serum of the bullæ. It fulfils the necessary requirements of Henle and Koch. Fehleisen obtained cultures of it by inoculating media with a piece of the skin from the spreading margin of the erysipelas. With cultures propagated from them he caused erysipelas in patients with cancer and tubercle, having observed that erysipelas has a curative effect upon those diseases. The *streptococcus* of erysipelas has been found in pus, blood, clothing, upon the skin, in the mouth, nose, and other orifices (Sternberg). Von Eiselsberg found it in the air of Billroth's wards, and Emmerich in the air of the dissecting-room.

CHAPTER V.

BACILLI OF WOUNDS.

The best known of the cocci found in wounds have now been described. I propose to give brief notes of some of the bacilli.

Bacilli are not often found in antiseptic wounds, although they are abundant everywhere, especially upon the surface of the body, in the mouth, nose, and alimentary canal. I have occasionally met with the *bacillus epidermidis* described by Bizzozero,[1] and sometimes a small short bacillus of the skin, probably the same as that which Unna and Tommasoli call the *bacillus ovatus minutissimus.*[2] These bacilli, however, were never found alone, but usually accompanied with *staphylococcus albus.* I have already remarked that the skin bacilli would probably be more often found in wounds if investigators would always proceed by the method of plate cultures.

It is rare now-a-days for wounds to have the odour

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[1] *Virchow's Archiv*, 1884, p. 441.

[2] *Monatsh. f. prakt. Dermat.*, Hamburg, 1889, bd. ix., p. 49.

of putrefaction. When it is present the bacilli which Hauser[1] has described as *proteus vulgaris, p. mirabilis,* and *p. Zenkeri* are found. The first is in my experience the commonest, but I have also met with putrefactive bacteria which evidently belonged to other species. Those called by Rosenbach *bacillus saprogenes* I., II., and III., ought, perhaps, to be included. Also the *bacillus pyogenes fœtidus* which has been met with by Passet in abscesses in the anal region, but which is now thought to be the same as the *bacillus coli communis.*

The bacilli which cause putrefaction and its frequent accompaniment, septicæmia, belong to a number of species, some of which are hardly known.

It must not be thought, however, that all the kinds of septicæmia are caused by bacilli, or by the bacilli of putrefaction. The disease is difficult to study because it is hard to obtain fresh specimens for examination. After death the intestinal and other cadaveric bacilli soon grow in the tissues and organs, and are a source of fallacy. The bacilli in some kinds of septicæmia are also exceedingly hard to stain in the tissues or to grow in media.

Of late I have examined several cases of septi-

[1] "Ueber Fäulnissbacterien und deren Beziehungen zur Septikæmie," Leipzig, 1885.

cæmia after amputation of the breast, amputation of the thigh, cellulitis of the neck, and erysipelas. In one or other of them bacilli were present at the seat of inoculation (*i.e.* the wound), in blood-clots leading from the wound, in the heart's blood, and in the capillaries of various organs, especially the lungs, kidneys, and heart. In the case following erysipelas the heart's blood was full of streptococci. Septicæmia seems to be more frequent when the wound putrefies.

Much has yet to be done to elucidate the bacteriology of these forms of sepsis. Most of the work hitherto achieved has been done by the inoculation of culture media with discharges from the wound. But it is known that only some of the bacteria which cause putrefaction grow in ordinary culture media in the presence of free oxygen.[1] Like the *bacillus septicus* and bacillus of tetanus, many of them are true anærobes. Systematic work by cultivation in oxygenless media, and by the investigation of sections of the tissues in the vicinity of wounds, has not yet been thoroughly undertaken or carried out.

There are, doubtless, many kinds of bacteria which

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[1] Flügge, "Micro-organisms with special reference to the Ætiology of the Infective Diseases," *New Sydenham Soc.*, translated by Watson Cheyne, 1890, p. 385.

do not grow upon ordinary culture media. Also, it is recognised that the sudden transference from one medium to another is often fatal to micro-organisms.[1]

The properties of the *bacillus pyogenes fœtidus*, which I have mentioned above, are uncertain. It has seldom been found alone, but usually in wounds which also harboured *staphylococcus aureus*.[2] It is even doubted by Baumgarten whether it ought ever to be called "pyogenes," or "pus-producing," although he allows it the adjective "fœtidus." Of late, as I have just said, the *bacillus pyogenes fœtidus* has been thought the same as the *bacillus coli communis.*

Wounds are sometimes infected with tubercle bacilli. I have seen this catastrophe after circumcision. The operation had been done with instruments which had been used for a case of tubercular disease. The instruments had not, I believe, been boiled. A few years ago I had under my care a case of tubercle due to the inoculation of tubercular virus into a sore upon the finger. Some cases of onychia maligna are of the same nature.

It is now easy to find records of similar cases. For

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[1] Metchnikoff, *Journ. Path. and Bacteriol.*, Edin. and London, vol. i., p. 15.

[2] According to Baumgarten ("Lehrbuch der pathologischen Mykologie," p. 504), this coincidence has been recorded by Tilanus, Cushing, E. Fränkel, and Sänger.

instance, a servant was inoculated upon the finger with tubercle. She cut herself with a spittoon which had been used by her tuberculous master. A veterinary surgeon tore his finger whilst dissecting a tuberculous cow, and acquired tubercle.[1] I have seen cases in which the lips had been inoculated with tubercle either by drinking-vessels or by kissing.

The *bacillus septicus,* the cause of acute spreading traumatic gangrene, the bacillus of tetanus, and the bacillus of anthrax are all occasionally found in wounds. The *bacillus coli communis* is not infrequent in wounds which involve the alimentary tract, and is almost invariably found in such as perforate the intestines. In pus which has a greenish or bluish tint the *bacillus pyocyaneus* occurs. The colour is due to a bluish-green substance, pyocyanin, which is secreted by the bacilli. This bacterium is one of the most interesting and easy ones to cultivate. It imparts a beautiful bluish-green tint to the culture media. When wounds were dressed with oiled lint this colour was often seen upon the dressing, and tinging the pus. Since sublimate dressings have been used it is seldom seen, and I have not met with the bacillus during the last two or three years.

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1 "The Channels of Infection in Tuberculosis," Sims Woodhead, *Lancet*, London, 27th October 1894.

Bacillus of Tetanus.

The tetanus bacillus may be seen in the pus and discharges of wounds, having been introduced with earth, mud, or dung. It is said to occur in the non-spore-bearing and in the spore-bearing stages. It stains readily with carbol-fuchsin. The spore stage is very characteristic, the spore grows at the end of the bacillus, and being large and globular, makes it like a drum-stick. The bacillus of tetanus fulfils the conditions of Koch and Henle. Being a strict anærobe, punctured wounds favour its growth. Its growth may also be favoured by the co-existence of other bacteria which use up oxygen, and thus bring about the required conditions. Many of the bacteria of septic wounds can use up oxygen to this extent.

Bacillus of Anthrax.

Every year one or two cases of anthrax enter the hospital. The patients have usually worked amongst hides or wool. I do not propose to refer at length to this bacillus. It is now so well known, and so easy to work with, that every one becomes acquainted with it during his course of bacteriology. When an anthrax pustule is seen cover glass specimens should be made

of its secretion. If no bacilli are found it must not, however, be thought that the case is not one of anthrax. In the last I examined none were seen, but mice inoculated with the same fluid died of anthrax. The square, sharply cut-off ends of the bacilli are distinctive.

Bacteria of Saliva and Mucus.

About the mouth wounds are apt to become infected with the various bacilli which abound in the saliva and buccal cavity. Some of these may, under certain circumstances, be pathogenic. The *bacillus salivarius septicus* is very fatal for rabbits. Its effects are seen when saliva is injected beneath their skin. The properties of saliva vary. That of an individual seems at one time to be harmless, and at another to be virulent. I believe that the bacilli of the saliva have some relationship to the pneumonia which sometimes occurs after excision of the tongue or fracture of the jaw.

Eisenberg's list of the bacteria of sputum includes thirty-nine species. They have, of course, been found under various circumstances and in various animals.

The nasal cavities also abound in bacteria, and their mucous discharges contain various cocci and bacilli.

During acute catarrh the bacteria are espeeially numerous. Eisenberg gives a list of these which have been found at various times; it includes ten non-pathogenic kinds and seven pathogenic. Amongst the latter are *staphylococcus pyogcncs aurcus, strcpto-coccus crysipclatis,* pneumobacillus, and the bacillus of glanders.

It is obvious that wounds should not be contaminated with the secretions of either the mouth or nose. I refer especially to wounds which are sewn up and oecluded.

Bacillus Septicus.

The *bacillus septicus* ought to be thoroughly studied and understood. It is unlikely that it will ever be banished from surgery, because, like the tetanus baeillus, it is an almost constant inhabitant of earth, mud, and dung—substanees which must oeeasionally get into accidental wounds. The *bacillus septicus* is often accom-panied by the bacillus of tetanus. If a teaspoonful of earth from a road, field, or garden be placed beneath the skin of a rabbit the animal usually dies, either of tetanus or of a disease which is called abroad malignant œdema or gaseous gangrene, and which corresponds to our acute spreading traumatic gangrene. This is caused

by the *bacillus septicus,* which is a large organism in comparison with most of those which have been mentioned. It is very like the *bacillus anthracis* in size and shape, and often grows in long strings. It has, however, slightly rounded ends, whilst the bacillus of anthrax has square clean cut ends, like a cigarette. The *bacillus septicus* is 1 μ broad and 3 μ to 4 μ long. It multiplies by fission and by spores. The spores occur in the single bacilli, and not in those growing in strings as in anthrax. They also bulge the bacillus, a further point of difference. The manner of its growth in gelatine explains in the clearest way its action upon human beings. It is a strict anærobe, and therefore multiplies at the bottom of the tube, as far as possible from the oxygen of the air. Next, it grows with great rapidity, and soon liquefies the gelatine, producing at the same time quantities of most offensive gases. The bacilli may be seen moving with speed in the liquid.

Now observe what happens when it is inoculated into man. To shun the oxygen of the blood it travels along the cellular tissues and lymph paths; producing gas, it causes an emphysematous crackling wherever it goes; owing to its mobility and rapid multiplication it spreads with ominous speed; and, last, the ptomaines which it produces soon poison its host.

Cases of acute spreading traumatic gangrene are not

as common as might be expected. It is probable that the bacillus has to be introduced in a particular way, especially by a punctured wound. I remember a case of Mr. Holden's in which a thorn covered with dung had been thrust into thc thumb; and another, under the care of Sir William Savory, in which it was introduced by a kick upon the leg which not only penetrated the skin, but also fractured the tibia. Thc boot with which the injury was inflicted was covered with mud. Such wounds must be very hard to disinfect; moreover, the two bacteria which are most to be feared in them, namely, the *bacillus scpticus* and the bacillus of tetanus, both possess highly resistcnt spores; these cau only be killcd by very strong chemicals acting for a long time. Acute spreading traumatic gangrene may also be caused by other gas-producing bacilli. An aërobic kind has been described by Dr. Klein, and the *bacillus coli communis* may also be one of its producers.

CHAPTER VI.

BACILLI OF WOUNDS.—*Continued.*

BACILLUS COLI COMMUNIS.

WHEN cultures are inoculated with the fluids from the peritoneal sac in cases of perforative peritonitis the *bacillus coli communis,* or, as it is often called, the *bacterium coli commune,* nearly always grows. I have found it in cultures inoculated from perforation of the stomach, duodenum, and small intestine. Great attention is now given to this microbe because it has been found in the fluid in the sacs of strangulated herniæ, in the pneumonia which often complicates intestinal obstruction,[1] in dysenteric abscesses of the liver, in abscess of the gall bladder, in prostatic abscess, and in excessive numbers in the diarrhœa of infants. Tavel and Welch have found it in wounds. Obviously it is of great importance to surgeons.

The shape of the *bacillus coli communis* is rather

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[1] Fischer and Levy, "Zwei Fälle von incarcerirter gangränoser Herniæ mit complicirender Bronchopneumonie," *Deutsche Ztschr. f. Chir.*, Leipzig, bd. xxxii., p. 252.

variable. As a rule the bacteria are short rods with rounded ends, about 0·5 μ broad and 2 μ long. Sometimes coccus forms are met with. Perhaps this diversity of form indicates the existence of more than one species. Tavel and Lanz,[1] who have lately written an admirable monograph on peritonitis, think that the *bacterium coli commune* is like that which was formerly called *bacterium termo,* and therefore includes several species.

The *bacterium coli commune* grows in pairs or in short strings. Spores have not been found. It stains well with aniline dyes, and is decolorised by Gram's iodine solution. It is indifferent, and grows either in the presence or absence of free oxygen. It does not liquefy gelatine. The growth upon the surface of media is in circular colonies, which are heaped up in the centre but thin and transparent at the edge, which is irregular. The central thick part of the colony is a yellowish white, which becomes almost brown as the culture grows older. The colonies in the depth have similar characters, but are smaller and spherical. It is important to note that bubbles of gas are formed in the gelatine. Variations in growth are common, so that a work like Sternberg's[2] ought to be consulted. The

[1] "Ueber die Aetiologie der Peritonitis," Basel, 1893, p. 160.

[2] "Bacteriology," New York, 1892. This is one of the clearest and most useful of the larger and more expensive works on bacteriology.

bacillus coli communis grows rapidly in all kinds of media, such as broth, gelatine, agar-agar, milk, and urine. In the last it soon causes decomposition of the urea, with the production of ammonia. It has probably often been described as the *bacillus ureæ.* It coagulates milk in a day or two, and this effect is useful for diagnostic purposes. As the bacillus of typhoid does not coagulate milk, although it is exceedingly like the colon bacillus in other respects. As I have already said, under certain circumstances the *bacillus coli communis* produces gas. This fact is of importance in relation to some kinds of peritonitis and emphysema of the tissues. Indol is produced when the *bacterium coli commune* is grown in media. Its presence is easily ascertained in broth by the usual nitric acid test.

Under some circumstances the *bacillus coli communis* is not very pathogenic. For instance, in perforative peritonitis the peritoneal effusion and lymph may contain countless numbers. Nevertheless the patient seems to be dying from acute intestinal obstruction and distension, and not from bacterial poisoning. Cases of this kind have recovered after I had done laparotomy, and relieved the distension by puncturing and incising the intestines, and washed out the peritoneum.[1] Of

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[1] "The Surgical Treatment of Diffuse Septic Peritonitis, with Successful Cases," *Med.-Chir. Trans.*, London, vol. lxxviii., p. 1, *et seq.*

course the washing out removes but a part of the bacilli. Those which remain are probably dealt with by the peritoneal cells. When large doses of cultures of *bacillus coli communis* are injected into the cellular tissues of guinea-pigs or rabbits suppuration ensues. These animals may be killed with very large subcutaneous doses. They suffer from a high temperature and diarrhœa, due to enteritis. The same occurs if the bacillus is injected into the blood stream. Injected in large doses into the peritoneum or serous cavities, the *bacillus coli communis* causes a fibrino-purulent inflammation. In thirty-one cases of peritonitis investigated by Fraenkel[1] *bacillus coli communis* was found in nine, *streptococcus pyogenes* in seven, *bacillus lactis aërogenes* (a close relation of *bacillus coli communis*) in two, *staphylococcus aureus* in one, and *diplococcus pneumoniæ* in one. In the eleven others were various kinds of bacilli, some of which have not been described.

The most contradictory statements are made about the pathogenic properties of the *bacillus coli communis*. Working with fresh cultures from cases of peritonitis, I have found it to be exceedingly pathogenic for some animals. Doubtless much depends upon its source and the dose which is used. Dr. Klein has identified the

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[1] A. Fraenkel, "Ueber peritoneale Infektion," *Wien. klin. Wchnschr.*, 1891, p. 265. This is a very valuable and exhaustive essay.

bacillus coli communis with a bacillus which causes inflammatory œdema with emphysema of the tissues. Quite recently the *bacillus coli communis* has been found by Eisenhart in a fatal case of puerperal infection. If this be confirmed its importance is obvious.

After death the *bacillus coli communis* soon emigrates from the intestines, and appears in the various closed cavities, organs, and fluids of the body. A source of fallacy is thus introduced into the study of human tissues. There are probably many other kinds of cadaveric bacilli, but although of great importance to investigators, singularly little seems to be known about them.

The conditions under which the *bacillus coli communis* passes through the intestinal wall are beginning to be understood. It seems quite certain that it passes through gut which has gangrened. Further, that injuries far short of gangrene may permit its escape, as in acutely strangulated herniæ in which the bowel is deeply engorged but viable.

This important topic has lately been investigated by Arnd,[1] who, by ingenious experiments, found that after from four to forty-eight hours of venous stasis caused

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[1] "Ueber die Durchgängigkeit der Darmwand eingeklemmter Brüche für Mikroorganismen," *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, 1893, bd. xiii., p. 173.

by strangulation, the rabbit's intestine permitted the passage of bacteria from the interior to the exterior. The viability of this intestine was definitely proved.

Arnd also ascertained that when such bacilli as *pyocyaneus, prodigiosus,* or *subtilis simulans,* had been given by the mouth, they passed through the walls of the constricted bowel.

These experiments are contradictory of those of Waterhouse and Ritter, but it seems reasonable to suppose that bacteria would transude the strangulated gut just as serous fluid does.

It is probable the hæmorrhage into or ulceration of the walls of the intestine also permit the passage of the intestinal bacteria.

The *bacillus coli communis* is said to be especially virulent when the bowels have been obstructed or inflamed, also in cases of diarrhœa, typhoid, or cholera.[1]

The typhoid bacillus, which is very closely allied to the *bacillus coli communis,* is met with in abscesses which follow typhoid fever. I have recently found it in an abscess over the tibia. It was still present and alive in the body a year and three months after the original attack of typhoid.

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[1] Treves, "Lettsomian Lectures on Peritonitis," 1894, p. 41. This author has, with much labour, collected a good deal of the literature referring to this important microbe.

I do not propose to say anything more about the bacteria which are found in septic wounds. Anyone who is convinced by the foregoing that the common diseases of wounds are caused by such bacteria as *staphylococcus pyogenes aureus, streptococcus pyogenes, bacillus septicus,* and so forth, must admit that bacteria ought to be excluded. This is the aim of aseptic surgery. Nor can the pathogenic bacteria be excluded apart from the non-pathogenic. As I proceed it will be seen that methods of wound treatment which admit one kind cannot exclude the others. Fortunately, the methods which exclude one exclude all, and, fortunately, those methods are simple.

But for the exclusion of bacteria from wounds we must know whereabouts they are, and how they can be killed. These will be the next topics, but before going on with them, the way to see bacteria in fluids from wounds may be shortly described.

The methods by which anyone can see bacteria in fluids from wounds, or in the pus from a cellulitis or from a pyæmic joint, or in pyæmic urine, are very simple and easy. Every dresser should practise them because the various bacteria only become entities to the mind when they have been seen and, if possible, grown.

Cover glass preparations have been repeatedly mentioned. They are so easy to make and stain that there

is no excuse for the non-examination of fluids from joints, peritoneal cavities, cysts, discharges from wounds, urine, and so forth.

The following is the way to proceed:—Thoroughly clean an extra thin cover slip by dipping it into strong nitric, sulphuric, or hydrochloric acid. If these be not at hand, spirit answers fairly well. After removing all traces of the acid, and thoroughly drying the slip, smear upon it the thinnest possible layer of the fluid. I have generally observed that too much is used. Next dry the film of fluid upon the cover glass by gently heating it over a flame.

The heat required for drying the film is learnt by practice. If the heat is too great, the bacteria shrivel up and refuse to stain. Koch[1] recommends that after the cover glass preparation is quite dry, it should be passed moderately quickly three times through the flame of a Bunsen's burner.

A safe and convenient plan for fixing cover glass preparations is to hold them for about a minute over the funnel of an argand burner, the flame of which has been turned down until the heat can be comfortably borne by the hand. The idea which I keep in mind in doing this is to dry the albumen in the fluid without

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[1] "The Ætiology of Tuberculosis," translated by Stanley Boyd, *New Sydenham Soc.*, 1886, "Microparasites in Disease," p. 77.

coagulating it; remembering also that bacteria, like other protoplasmic elements, are shrivelled up by heat.

When thin fluids like urine or broth culture fluids have been dried upon the slip, great care is required in washing away the superfluous dye. A very gentle waving to and fro in a glass of water is often all that can be done with safety. If the dye does not wash off in water, equal parts of spirit and water may be cautiously tried, with an after washing in water.

The best and most convenient stain for all ordinary purposes is Ziehl's solution of carbol-fuchsin.[1] It is by far the best stain to keep in stock. It retains its properties for a long time, and there are hardly any bacteria which it will not stain. It has the great advantage of not fading, and is an excellent colour for microphotography. The solution is made as follows:—Put 10 grammes of fuchsin crystals in a small glass mortar, and pour over them 10 cubic centimetres of absolute alcohol. Next add 90 cubic centimetres of a 5 per cent. solution of pure carbolic acid in water, and stir with a glass rod until all the dye is dissolved; pour into a stoppered bottle, and label "Solution of Carbol-fuchsin." In this preparation the alcohol helps to dis-

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[1] Kühne, "Practical Guide to the Demonstration of Bacteria in Animal Tissues," gives many hints on staining. It has been translated by Dr. V. D. Harris.

solve the fuchsin, and it is well to add a little more from time to time: the solution of carbolic acid acts as a mordant and as a preservative. This stain must be kept in a stoppered bottle, as the alcohol and carbolic acid are volatile; also it must be filtered each time it is used. To stain the cover glass preparations, pour a few drops of the carbol-fuchsin solution upon a filter, and allow it to drop upon the film. Leave it to soak for five minutes, and wash off the excess of the dye with water, or alcohol and water, until the film is sufficiently decolorised to be transparent. Then dry the film again with a gentle warmth, cover it with a drop of Canada balsam dissolved in xylol, and mount upon a glass slide and label at once. To examine the specimen properly, a microscope which has an Abbé's sub-stage condenser, a $\frac{1}{12}$ in. oil immersion objective, and a good fine adjustment is required.

Professor Hamilton, in his new and admirable work on "Pathology," gives some excellent common-sense rules for the choice of a microscope. It is impossible to attempt modern pathology without such an instrument as that which has been mentioned.

The bacillus of tubercle and the bacillus of leprosy retain fuchsin so tenaciously that they do not give it up even in the presence of strong acids.[1] Should, there-

[1] Fuchsin is a basic aniline dye, and combines with an acid after the manner of other bases.

fore, tubercle or leprosy bacilli be suspected, advantage may be taken of this peculiarity. Washing in a 10 per cent. solution of nitric acid will decolorise all bacteria except those of tubercle or leprosy. It is to be remembered, however, that prolonged exposure to strong acids will decolorise tubercle and leprosy bacilli. Wash, therefore, for a few seconds only, and until the film becomes of a slate colour, not until all its colour has departed.

Gram's Method of Staining.

Before I proceed with the sources of wound infection another useful method of staining may be mentioned. Gram's method demonstrates with clearness erysipelas and nearly all the pus cocci, especially *staphylococcus pyogenes aureus* and *albus* and *streptococcus pyogenes.* It is as follows :—Prepare a solution of aniline oil water by shaking up some aniline oil with distilled water (a stock bottle of this solution is usually kept). Filter some of this into a clean test-tube until a quarter full. Add to this aniline oil water a drop or two of a saturated alcoholic solution of gentian violet or methyl violet. After this addition the solution should be dark but translucent. If it has become turbid add a few drops of alcohol. Filter a little of this staining

solution into a clean watch glass, and place the cover glass preparation or section into it for three to five minutes. Sections of tissues are transferred into it direct from alcohol. After staining, the preparation is well washed in clean water, and placed for a minute in some of Gram's iodine solution, which is made as follows :—Pure iodine, 1 gramme, iodide of potassium, 2 grammes, distilled water, 200 grammes. The specimen emerges from this a rich brown, but after washing in alcohol and water it loses this, and becomes a sort of slate colour. After this stage the cover glass preparation is put up with Canada balsam; sections are dehydrated, clarified with bergamot oil, then with xylol, and mounted in the usual way. It is dangerous to use clove oil, as it decolorises the sections. Gram's iodine solution acts both as a decolorising reagent and as a mordant. The bacteria stand out as almost black objects, and in sections are upon a ground of slate-coloured or brownish tissue.

Gram's method requires practice, but gives beautiful results when successful. In sections which have not been well decolorised by washing in spirit little particles of dye are apt to remain. These are easily mistaken for cocci. They are, however, distinguished by the variability of their sizes and shapes.

PART II.

CHAPTER VII.

SOURCES OF INFECTION.

We now come to the sources of infection. Bacteria, such as those which I have mentioned, are introduced into wounds from the air; by water or anything brought in contact with wounds; from the skin of the patient; from the skin of the hands and arms of surgeons and nurses; and sometimes they are carried into wounds by the patient's blood stream. All this applies, of course, to cases in which no local sepsis exists before the operation; these will be taken separately, and their disinfection described.

The chief of the above forms of infection are air infection, water and contact infection, and skin infection. Infection through the circulation, auto-infection, is rare.

Air Infection.

The air has long been thought a potent source of infection. It is probable that the work of Lister and of Tyndall gave surgeons an exaggerated idea of the

quantity of bacteria in the air. Tyndall drew attention to the swarms of dust particles in the air of cities and dwellings. Possibly by a confusion of thought the abundance of these particles may have been taken to indicate the actual quantity of bacteria in the air. At any rate, surgeons used to try either to exclude air from wounds, or to surround them with a purified atmosphere. This was the reign of the spray.

At present there is a reaction against air infection and the spray, and now some seem to think that the air is harmless. This is not justified by the facts. Haegler[1] found *staphylococcus pyogenes aureus* in plate cultures exposed for five minutes in one of Socin's wards. The air of Billroth's wards was found to contain all kinds of moulds, yeasts, and bacteria.[2] Amongst the last were various bacilli and cocci, and the streptococcus of erysipelas. The appearance of this was simultaneous with the entrance of cases of erysipelas into the wards. The streptococci were obtained by exposing culture media in plates near the heads of the patients. Von Eiselsberg,[3] who records this, says that

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[1] *Beitr. z. klin. Chir.*, bd. ix., p. 3.

[2] Von Eiselsberg, "Nachweis von Erysipelkokken in der Luft chirurgischer Krankenzimmer," *Arch. f. klin. Chir.*, Berlin, 1887, p. 1.

[3] *Op. cit.*, p. 17.

Emmerich has found the streptococcus of erysipelas in the air of a dissecting room.

Mr. Waring[1] exposed gelatine plates for a minute in our operation theatre and wards, and afterwards found colonies of various kinds of bacteria, including *staphylococcus pyogenes aureus* and *albus.* In the air of the isolation ward for crysipelas he found *streptococcus pyogenes seu erysipclatis.*

The tubercle bacillus has over and over again[2] been found in the dust of wards where phthisical people were collected and allowed to expectorate their highly infectious sputum.

In addition to these well-recognised pathogenic bacteria the air may contain other cocci and bacilli together with yeasts and moulds. Obviously much will depend upon the sourccs of the dust. As I have pointed out, the dust from roads and fields nearly always contains the *bacillus scpticus,* the bacillus of tetanus, and the *bacillus coli communis.*

The laws which regulate the numbcr of bacteria in air are now bcginning to be understood. In the air of rooms and dwellings they are always prcsent, but dryness and disturbance arc essential for thcir presence in

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[1] *St. Barth. Hosp. Rep.*, London, vol. xxix., 1893, p. 101.

[2] See Cornet on "The Diffusion of the Tubercle Bacillus External to the Body," *Med. Rec.*, N.Y. 1889, p. 222; also, *Ztschr. f. Hyg.*, Leipzig, bd. v., 1889.

large numbers. Neumann[1] found from 80 to 140 bacteria in ten litres of the air of the wards of the Moabit Hospital after the wards had been swept and the convalescents had risen. At night when all was quiet only four to ten were found; ventilation did not increase their numbers.

The presence or absence of moisture has an important relation to the dissemination of bacteria in the atmosphere. Nägeli's[2] experiments showed that bacteria could hardly be detached from moist surfaces—very strong currents of air might occasionally carry particles of fluid containing bacteria a short distance through the air, but they soon subsided. The inability of bacteria to detach themselves from moist surfaces explains their absence from the breath. Bacteria are present, however, in expired air when, as in coughing or sneezing, it carries with it particles of saliva or of mucus; but it is easy to prevent either of these entering wounds. Fluids, such as pus or blood, do not part with bacteria to the atmosphere until they have been dried and pulverised; but when converted into dust the particles of pus or blood may be virulent for many

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[1] "Ueber den Keimgehalt der Luft in städt-Krankenhause Moabit," *Vrtljschr. f. gerichtl. Med.*, Berlin, bd. xlv., 1886, p. 310.

[2] Quoted by Flügge, "Micro-organisms with special reference to the Ætiology of the Infective Diseases," *New Sydenham Soc.*, 1890, p. 687, *et. seq.*

months. Tubercle bacilli retain their vitality in the dry state for six months,[1] so that the purulent sputum of tuberculous patients is a danger as great as is the milk of tuberculous cows. No wonder, when we consider the laxity with which the phthisical are treated, that "a third of the deaths between fifteen and forty-five in England is due to this terrible disease."[2]

Marpmann[3] seems to have had little difficulty in finding tubercle bacilli in the dust of the streets of Leipzig. He claims that they can be grown, and that tuberculosis can be produced with them.

It is known that pyogenic organisms, such as *staphylococcus pyogenes aureus*, live for years in culture media. The duration of their life in dust is hardly known, but is doubtless considerable. The spores of anthrax, tetanus, and of the *bacillus septicus* live for an indefinite period in dust and earth, and merely require to be placed under proper conditions of warmth, moisture, and nutriment to sprout and give birth to fresh swarms of virulent bacilli.

Tyndall,[4] in his admirable experiments with closed chambers, definitely proved that when the air is still

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[1] Flügge, *loc. cit.*, p. 737.

[2] Fagge's Medicine, vol. i., p. 1052.

[3] "Die Untersuchung des Strassenstaubes auf Tuberkelbacillen," *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, bd. xiv., 1893, p. 229.

[4] "Essays on the Floating Matter of the Air," 1881, p. 131, *et seq.*

all the dust and bacteria gravitate, and that thus a pure atmosphere, similar in this respect to that over the ocean or mountain tops, is produced. Bacteria gravitate in the same manner in operation theatres and dwelling-rooms, as was shown in Neumann's experiments.

Bearing upon this point we may quote Flügge, who says that in ordinary air one to five hundred living bacteria have been found in each cubic metre. He adds that this proportion becomes much less in rooms which have not been disturbed.[1]

The lessons to be learnt from this are clear. Dust is to be avoided, especially dust which has been mingled with pus, blood, or sputum. Obviously those fluids, or any other infected materials, ought never to be allowed to dry, but be removed or wiped up at once. It is also desirable in planning wards and operation theatres to have smooth and polished surfaces, such as retain but little dust, and are easily wiped down with cloths wet with disinfecting solutions. The frames of doors and windows should be flush with the walls, and corners ought to be rounded. Every chink and cranny ought to be open to inspection, and arranged for easy and efficient dusting. Curtains

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[1] *Op. cit.*, p. 687.

should only be used where absolutely necessary, and should be frequently washed.

When it is necessary to prepare a private dwelling-room for an operation it should be done the day before, and left for the dust and bacteria of the atmosphere to subside.

The risk of air infection during operations is diminished by rapidity in operating; by keeping the wound covered as much as possible with an antiseptic sponge or layer of gauze; and by irrigating it with a stream of antiseptic lotion. When a large cavity like the abdomen is opened the protection of a flat sponge is particularly important. If, in the midst of an operation, it becomes necessary to move the table or light the gas, the wound and field of operation should be covered with sterilised towels until the change is completed. Neither the operator nor any of his assistants should assist in moving the patient or in lighting the gas. Should they do so they ought to take special pains to immediately disinfect their hands and arms.

Water Infection.

Ordinary tap water contains an extraordinary array of bacteria. Most of these are saprophytes, and can,

therefore, only live upon dead tissues; but others are pathogenic. Eisenberg tabulates twenty-six species of non-pathogenic micrococci and fifty-eight of non-pathogenic bacilli as having been found in water. Ten kinds of pathogenic bacteria have been found, including *staphylococcus pyogenes aureus, bacillus coli communis,* and the *proteus vulgaris* and *mirabilis.* But Eisenberg's list is already incomplete. Landmann,[1] whilst examining the water of a well for diphtheria bacillus, found that it contained *streptococcus longus,* which was most virulent for mice. The bacillus of leprosy has recently been found in abundance in water used by lepers.[2] Obviously ordinary care demands that only sterilised water be brought in contact with wounds, particularly those which are closed and sealed with dressings.

Although the saprophytes which inhabit water cannot flourish in living tissues, yet it is dangerous to introduce them into cavities in which blood-clot, pus, or albuminous fluids can collect. Such collections provide saprophytes with suitable food, so that they multiply and manufacture sapric substances, which being absorbed cause the phenomena of sapræmia.

The pathogenic bacteria of water are seldom or never

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1 *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, bd. xiv., 1893, p. 430.

2 "Report of the Leprosy Commission," 1893, p. 403.

present in numbers, but it would be unwise to ignore their occasional occurrence. Therefore the water which is applied to wounds or used for irrigation is always mixed with chemicals or boiled. I have never known an instance in which boiling for five minutes has failed to disinfect ordinary tap water or distilled water. Moreover, water becomes sterile when mixed with small quantities of chemicals.

Some time ago I tested the ordinary supply of hot water at the Great Northern Hospital.[1] This supply is pumped up to the operation theatre from large boilers in the basement. To test the water the operation theatre basin was filled in the usual way, and the water inoculated into gelatine tubes, which remained sterile. Mr. Waring[2] tested the hot water at St. Bartholomew's in the same way. Water taken from the hot-water tap of the operation theatre contained several varieties of micrococci and bacilli, but none of them appeared to be pathogenic.

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[1] "Report on Aseptic and Septic Surgical Cases," *Brit Med. Journ.*, London, 28th May 1892.

[2] *St. Barth. Hosp. Rep.*, London, 1893, vol. xxix., p. 101.

CHAPTER VIII.

CONTACT INFECTION.

INSTRUMENTS are the most potent source of wound infection. However well they are made, and however well mechanical means are used to cleanse them, particles of blood, pus, or infective material must often lodge in their joints and serrations. Suppuration has been so long regarded as a normal event—indeed, books still talk about laudable pus—that direct evidence of the infection of wounds with pyogenic organisms is hardly to be found. The inference, however, is none the less clear. But in other diseases than suppuration direct evidence is at hand. In speaking of tubercle I gave instances of its transmission by instruments. Roswell Park[1] says that Thiriar lost ten cases of major operation from tetanus before he discovered that his hæmostatic forceps were the source of infection. It would be easy to cull from the records of midwifery and obstetric surgery instances of the conveyance of infection by forceps and other instruments.

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[1] "Lectures on Surgical Pathology," St. Louis, 1892, p. 175.

The mere fact of an instrument being new from the maker is no guarantee of its sterility, or even of its cleanliness. As Reverdin says in his excellent manual,[1] our instruments come from the greasy and dirty hands of the workmen, their crevices full of oil and filth; whilst the instruments of veterinary surgeons, pathologists, knackers, and even those used for inoculations in the laboratory, are sharpened upon the same stone.

A bacteriological examination of the instruments of bygone times would have been instructive. I once obtained a set of instruments which had been used for a case which died of pyæmia. Material from amongst the teeth of the forceps did not infect gelatine. Some blood upon a holder with an ivory handle grew a micrococcus, probably *staphylococcus pyogenes albus*. I afterwards learnt that the forceps had been boiled *after* the operation, and just before my examination. Moreover, they had previously been used for another case which died of pyæmia.

But anyone who has performed inoculation experiments upon animals with cultures of tetanus, anthrax, tubercle, or the pyogenic cocci needs no arguments to convince him of the danger of the conveyance of infection by instruments. Every one should see inoculations performed with some of the more virulent microbes.

[1] "Antisepsie et Asepsie chirurgicales," Paris, 1894, p. 79.

My own bacteriology classes would not, as a rule, believe that a mouse would die of anthrax after it had been merely punctured with a needle conveying a dose of anthrax inappreciable to their unaided senses.

In laboratory work no one would dream of touching culture media with unsterilised instruments. If such were used a growth would certainly ensue. The nature of the growth would depend upon many circumstances, but, as a rule, would consist of moulds, sarcinæ, hay bacilli, white micrococci, or other common inhabitants of air and dust. Had the instruments previously been used for an inoculation with anthrax or *staphylococcus pyogenes*, they, too, might be expected to grow.

Towels.

The towels, sponges, catgut, silk, and dressings may all be contaminated by air, dust, or water, and contain, therefore, bacteria such as I have mentioned; but, in addition, each thing may have upon it bacteria of particular kinds. For instance, I have found in towels, besides *staphylococcus pyogenes albus* and moulds, a bacillus which grew with a strong sebaceous odour, and had, without doubt, been derived from some one's skin. Hobein[1] found that underclothing was also infected by

[1] *Ztschr. f. Hyg.*, Leipzig, 1890, p. 218.

the bacteria which Bizzozero has described as living in the skin.

It is to be expected that towels would contain skin bacteria, but they may also be infected in a host of other ways. It is hardly necessary to mention the uses to which towels are put, or to point out that those which have been used in the pathological, anatomical, or other departments may all be mingled and washed with those which are used at operations.

Sponges.

The sponges which are used in operations ought to be of the soft fine Turkish variety. A glance at the way in which these articles are prepared for the market shows that even new sponges leave much to be desired, and that they may harbour all kinds of bacteria.

After sponges have been fished up by divers they are exposed to the sun until decomposition has begun. Then they are beaten in running water to remove the soft animal matter. If this part of the process is postponed for only a few hours after the sponge has been exposed a whole day to the air, it is almost impossible to completely purify it.[1] After draining, it is hung up

[1] See article, *Encyclopædia Britannica*, 9th edition, vol. xxii., p. 429, 1887.

in the air to dry, and then, with others, finally pressed into bales. As sponges are sold by weight, sand is often added as an adulteration. Before sponges are sold to the public by dealers they are cleansed of sand and bleached with sulphurous acid.

I have usually tested the sterility of sponges after they have been prepared for operations. These sponges have been commendably aseptic. Once I met with *staphylococcus pyogenes albus,* and once with a micrococcus, probably derived from the hands. Upon one occasion I met with a bacillus about the size and shape of tubercle bacillus. This grew singly, and in short leptothrix. At summer temperature it grew slowly near the surface of the gelatine as a delicate white cloud, and produced a slow liquefaction. On agar-agar it grew on the surface and in the depths, the surface growth being a smooth white streak with slightly irregular edges. The bacillus made broth slightly turbid. I have not before met with any bacillus exactly like this one.

Catgut.

The catgut[1] which is sometimes used for ligatures and sutures is, without strict and careful preparation,

[1] Those who are interested in this topic will find the fullest information in Brünner's paper, "Ueber Catgutinfektion." *Beitr. z. klin. Chir.*, Tübingen, 1890, vol. vi., p. 98, *et seq.*

a dangerous source of infection. Nevertheless it has such incontestable advantages for many purposes that its use is not likely to die out. On the contrary, as our methods of preparing it improve it is likely to enjoy a wider popularity.

Catgut is made from the entrails of sheep. In the process of manufacture the mucous membrane and most of the circular muscle-fibres are scraped away. Nevertheless it is highly improbable that all the intestinal bacteria are removed. Indeed, there is much evidence to the contrary. Moreover the intestinal walls may themselves be infected. Volkmann has described two cases of anthrax after amputation of the breast. He attributed these to the catgut used for tying the vessels. Volkmann's evidence, however, leaves much to be desired. Kocher and others have described cases which leave no doubt as to the dangers of catgut infection.

Zweifel saw septicæmia follow its use, and Mosetig von Moorhof lost patients from suppuration around omental and ovarian pedicles which had been tied with it.

Five or six years ago catgut soaked in carbolic oil was used for wounds. I found that most samples of this material infected nutrient gelatine. Reverdin and Massol[1] found that raw catgut always infected gelatine

[1] "Antisepsie et Asepsie chirurgicales," p. 131.

or agar-agar. Colonies also grew after it had been soaked in oil of juniper or alcohol. Zweifel found masses of bacteria between the lamellæ of catgut, some of which had been used for operations; but, as Brünner says, these may have been dead. In sections of catgut made with the microtome Brünner saw quantities of bacilli and cocci.[1] This author obtained growths of bacteria from most specimens of catgut prepared with carbolic oil, juniper oil, or chromic acid. Macpherson[2] also found that many specimens of sulphuro-chromic gut infected culture media.

Silk.

White silk, such as is used for sutures and ligatures, passes through a process of manufacture which tends to ensure sterility. Macpherson[3] says, "The silk threads are 'thrown' in China and Italy (chiefly in Milan), and come into this country coated with the dried viscid material of the cocoon, or, as it is technically called in the gum. The processes to which these threads are subjected in English manufactories have in view the removal of the gum, which is a valuable

[1] *Loc. cit.*, p. 148.

[2] "Antiseptic Preparations of Catgut and Silk," *Med.-Chir. Trans.* London, vol. lxxv., 1892, p. 227.

[3] *Loc. cit.*, p. 234.

mordant, and the production of a thread as pure and white as possible. The gum is removed by boiling, and the threads are afterwards washed with the best curd soap. The soap is then removed by the process of 'stoving,' *i.e.*, placing the threads for six to twelve hours in sulphur kilns, Finally, the threads are bleached by one or other of the patent bleaching powders. 'Surgical' silk, which is the whitest silk obtainable, and more resistant than inferior qualities to the action of heat, is subjected twice to the process of 'stoving.'"

As Macpherson says, boiling, stoving, and bleaching are powerful germicidal processes.

But although great care is taken to keep silk as clean as possible, it is usually infected before it reaches the surgeon. Macpherson grew bacteria which liquefied gelatine from silk in a surgeon's pocket case. Silk lying about a sitting-room also gave a growth. Carbolised silk from instrument makers usually infected culture media. Generally speaking, unprepared silk came exceedingly well out of its trial, and has not many of the dangers of catgut.

CHAPTER IX.

SKIN INFECTION.

THE human skin and its appendages teem with bacteria. Nearly every species is represented—cocci, sarcinæ, saccharomyces, moulds, and bacilli abound in cultures inoculated with scrapings of the normal skin. Those who are interested in this subject will find an exhaustive list in Eisenberg's indispensable work,[1] in the writings of Unna and his fellow-workers,[2] and in Mr. Damman's essay.[3]

The bacteria abound in normal skin, and their numbers and varieties are increased in disease. For some years I have tested the skin of persons operated upon by cutting off a piece of skin and placing it in nutrient broth. Although the most determined efforts had been made to disinfect this skin, I have grown from some specimens of it *staphylococcus pyogenes albus*, *strepto-*

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[1] "Bakteriologische Diagnostik."

[2] *Monatsh. f. prakt. Dermat.*, Hamburg, bd. vii., p. 817, and bd. ix., 1889, p. 50, and elsewhere.

[3] "Preliminary Note on some Micro-organisms of Normal Skin," *Brit. Med. Journ.*, London, 16th July 1892, p. 122.

coccus pyogenes, staphylococcus pyogenes aureus, sarcina lutea, bacillus epidermidis, staphylococcus epidermidis albus, and *diplococcus epidermidis* (the microbe which produces the acrid and offensive odour). From scrapings of healthy skin, in addition to the long list which Eisenberg gives, I have separated *micrococcus roseus.*

In some diseases of the skin—eczema, for instance—bacteria are more numerous, and in other diseases special kinds are found. The streptococcus of erysipelas and the tubercle bacillus have a not infrequent influence upon the results of operations.

The presence of quantities of bacteria in healthy skin throws doubt upon observations which show their presence in certain diseases. Nevertheless it may be mentioned that in a case of pyæmia Von Eiselsberg[1] found that *staphylococcus pyogenes aureus* was present in the osteomyelitis of the femur, in the blood, in the metastatic abscesses, and lastly, in the sweat of the forehead.

Tubby,[2] in examining sections of skin from a case of acute suppurative periostitis, found the sweat glands more dilated than usual, and crowded with micrococci.

In sections of healthy skin I had no difficulty in

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[1] "Nachweis von Eiterkokken im Schweisse eines Pyämischen," *Berl. klin. Wchnschr.*, 1891, No. 23.

[2] "The Pathology of Acute Infective Periostitis," *Guy's Hosp. Rep.* London, vol. xlvii., 1890, p. 77, &c.

seeing cocci, diplococci, and bacilli in the epidermis and in the mouths of the hair follicles. Sebaceous matter, squeezed from a sebaceous gland and made into a cover glass preparation, is a mass of cocci, diplococci, and bacilli, with occasional epithelial-cells. After an area which possesses numerous sebaceous glands had been washed with soap and water, then with perchloride of mercury lotion, 1 in 1000, and lastly with absolute alcohol, its glands were squeezed and cultures inoculated from its surface. The result was a plentiful growth of long and short bacilli, leptothrix, monococci, diplococci, and staphylococci. A perspiring surface was cleansed in the same way, and as soon as the sweat reappeared nutrient material was inoculated with it, and grew quantities of staphylococci, and, in old cultures, some bacilli and leptothrix. It is interesting to note that the sweat gave a growth of cocci with few bacilli, whilst sebaceous matter gave bacilli with few cocci.[1]

The fissures beneath the nails are the special homes of bacteria. I have grown from a bit of nail what I believe to be *streptococcus pyogenes*, and on another occasion *staphylococcus albus*. In both cases a deter-

[1] Most of these notes upon bacteria in the skin are from my "Report on Aseptic and Septic Surgical Cases, with special reference to Infection from the Skin," *Brit. Med. Journ.*, London, 28th May 1892; and from my "Report on the Disinfection of Skin," &c., *Brit. Med. Journ.*, London, 27th January 1894.

mined effort had been made to disinfect beneath the nails. Fürbringer also found it most difficult to cleanse the nails. Mere washing was of no avail. I do not believe it possible to disinfect the nails except by cutting them as short as possible.

The relation of the bacteria of the skin to suppuration still requires elucidation. Since I have learnt to look upon the skin as a source of infection, and since so much pains have been taken to disinfect it, suppuration has been exceedingly rare. In such complicated and difficult cases as those of radical cure of hernia our proportion of suppuration is 10 per cent., or less, and a serious sepsis has never occurred. Perhaps the adjective *pyogenes* ought not to be added to some of these skin bacteria until they have been definitely proved to possess the power of causing suppuration. Nevertheless I have found cultures of bacteria from the skin decidedly pathogenic for white mice, and occasionally for rabbits.

In rabbits I found that a fatal result usually followed the injection of a fluid composed of skin scrapings suspended in normal saline solution into the auricular vein. Some rabbits died at once—killed, perhaps, by the coarse particles; others died some days or weeks afterwards. Gelatine cultures inoculated from the same kind of fluid, made of normal saline

solution and skin scrapings, soon became liquid, and contained a great many kinds of microbes—cocci of various sizes, diplococci, staphylococci, chains of from four to twelve cocci, some chains consisting of large, others of small elements, numbers of very small short bacilli aggregated into small groups, a larger spore-containing bacillus with rounded ends, and leptothrix. The liquefied gelatine which contained these bacteria seemed more virulent than a mere solution of skin scrapings. An intra-venous inoculation of five to ten drops soon made rabbits ill; and when they died their lungs were usually inflamed and engorged, especially near the periphery.

When cultures which had been inoculated with the contents of sebaceous glands were introduced into the subcutaneous tissues of mice, they killed the animals in three or four days, causing œdema, suppuration, and ulceration, with loss of hair. These cultures had the peculiar disagreeable odour possessed by the contents of sebaceous retention cysts.

The cultures with which these experiments were made contained several kinds of bacteria. Much remains to be done before we shall know the effects of pure cultures. Then it will probably appear that some kinds are harmless and others harmful in different degrees.

I have made a few experiments in this direction, and found that pure cultures of *bacillus epidermidis,* cultivated from skin scrapings and separated by the method of plate cultures, had the same effect upon mice as mixed cultures.

Small doses of pure cultures of *diplococcus epidermidis albus* may be injected into the veins of rabbits without apparent injury. There is usually redness and slight suppuration at the seat of inoculation. A larger dose injected into the cellular tissues causes inflammation and œdema with some purulent infiltration. The *diplococcus* (or *staphylococcus*) *epidermidis albus* was common in those cases of slight subacute suppuration which used to occur more often than they do now. In some cases plate cultures showed that the micrococcus was mixed with *bacillus epidermidis.* Now and then the cocci grown from the wounds had a disagreeable acrid odour, such as is observed when uncleanly people remove their vestments. The bacteria of the skin are often found in the vicinity of wounds which have healed by primary union, and with none of the usual signs of inflammation. My belief is that in these cases the bacteria emerged from the depths of the sweat and sebaceous glands after the wound in the skin had adhered.

It is a pure assumption that these skin bacteria are

the cause of slight subacute suppuration, but, as I have said, as the bacteria have been eliminated by cleansing the skin, the suppuration has ceased to occur. Moreover, skin which contains one kind of microbe may contain another. Safety is attained by excluding all.

One of our cases of suppuration was very instructive. The patient was not very well before the operation, and a bit of her skin cut off at the operation and dropped into broth grew a pure culture of *staphylococcus pyogenes aureus.* The wound suppurated, and the pus contained the same microbe.

This plan of cutting off a bit of skin and dropping it into broth is one of the best ways of testing the disinfection of skin. Sometimes it is tested by putting scrapings into nutrient material; at others by merely dabbing the fingers upon plate cultures of gelatine or agar-agar, or by dipping them into broth.

Auto-Inoculation.

The inoculation of a wound through the patient's own blood stream may occasionally occur. It is, of course, very difficult to obtain satisfactory evidence upon this point. Reasoning from analogy, its occurrence is quite possible. I have before me the notes of a case of suppuration which followed a simple fracture of the

ulna in an apparently healthy schoolboy. It would be easy to collect similar examples. It is now one of the commonplaces of pathology that bacteria are carried by the blood stream from septic wounds to the internal organs—as, for instance, in pyæmia, and I might add, in septicæmia; so why should they not be carried to a wound? Some years ago I cut down upon a median nerve which had been involved in a scar. The boy seemed perfectly well, and his wound painless and apparently healed. One day he was seized with a diphtheritic sore throat. He became ill, and the wound in his arm suppurated. The experiments of Rosenbach, Wyssokowitsch, Kocher, and others have shown that injured tissues arrest bacteria which are circulating in the blood.

Thus auto-inoculation of wounds may occasionally occur. It is, however, too rare to afford a plausible excuse for bad results.

Immunity.

Before describing the methods by which instruments, sponges, towels, skin, and so forth are disinfected, I would like to refer again to a question which naturally arises, and is often asked, viz., why, if bacteria are so wide-spread and so harmful, does any one survive an

operation in which asepsis is not secured? To answer this would require a discussion of the great and growing question of immunity. This would be quite beyond the scope of these notes. The natural immunity which some species of animals enjoy, and the immunity which they acquire or have imparted to them, have all been briefly referred to. Vaccination against the smallpox is an example of acquired or artificial immunity, and to it may be added vaccination with the antitoxins of tetanus and diphtheria.

But the most important branch of this subject to surgeons is that which deals with local immunity. In describing *staphylococcus pyogenes aureus* I said that the peritoneum was immune against small doses of that microbe, but that the immunity was lost if the integrity of the serous membrane had been destroyed by exposure to air, by the action of chemicals, by tearing or laceration, or by bruising. Similar principles apply to the other tissues, and their bearing upon the practice of surgery is too obvious to call for comment.

But this resistance of the healthy living tissues to bacterial invasion cannot be relied upon. It is a thing beyond the control of the surgeon, whilst asepsis is not. No one would exchange a certainty for an uncertainty.

PART III.

CHAPTER X.

DISINFECTION AND ANTISEPSIS.

THE commonest bacteria have now been described. I have also mentioned where they are found, and how they enter wounds. The next step is to tell how to keep them out of wounds.

This requires a knowledge of disinfection and of antisepsis. An antiseptic has already been defined as that which prevents or retards the growth of bacteria, and a disinfectant as that which kills them outright. These distinctions must now be kept clearly in mind.

Disinfection may be carried out by heat, chemicals, or by filtration. Sunlight, electricity, and some mechanical processes might also be enumerated, but have not the same value as the others. Nevertheless, in planning hospitals the value of sunlight ought not to be ignored. It has the most potent influence upon bacteria, in preventing or retarding their growth, and in purifying the atmosphere. Later it will be seen that mechanical measures, such as scrubbing, are an important part of the disinfection of the skin. Of all

methods of disinfection heat is the simplest, cheapest, and best. Chemicals occupy the second rank, but are treacherous and difficult to use. Filtration by Chamberland's filter, or Berkefeld's modification of it, may be of occasional use for the sterilisation of water. This, however, is done more easily and certainly by heat.

The practice of aseptic surgery does not consist in the slavish use of chemicals. They are merely adjuncts, and not an essential part of the system. Some surgeons try to do without chemicals. They pin their faith upon heat in its various forms for the elimination of bacteria.

It is, perhaps, doubtful what the practice of the future will be. As our hospitals are at present constituted, chemicals can hardly be avoided. Some time since, Mr. Butlin[1] treated his cases with a mininum of chemicals, and with materials sterilised with heat. Out of sixty-one cases, twenty-nine suppurated. Bloch,[2] too, seems to have pursued the same system with moderate success. The results of the mixed method of asepsis, which, as I have already said, utilises both heat and chemicals, has given me in hospital practice about six per cent. of suppuration. But much of this was trivial and not progressive. Moreover, as house

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[1] *St. Barth. Hosp. Rep.*, London, vol. xxix, 1893, p. 89, *et seq.*

[2] *Rev. de chir.*, Paris, 1890.

surgeons, dressers, sisters, and nurses acquire the principles of aseptic surgery, the proportion of suppuration tends to diminish.

Disinfection by Heat.

Disinfection by heat is governed by certain laws. First, all cocci and non-spore bearing bacilli are easily killed by moderate heat acting for a short time. Second, spores are only killed by considerable degrees of heat acting for a long time. Third, moist heat is much more efficacious than dry heat; and fourth, fluids of small nutritive value are easier to disinfect than those of high nutritive value. Thus water is easier to disinfect than urine, and urine is easier to disinfect than milk, or blood, or sputum.

Generally speaking, a high degree of dry heat kills bacteria quicker than a lower degree, and the same applies to moist heat.

Pasteur and others have found it easier to kill bacteria in acid media. In some alkaline fluids the bacteria seem to be in some way protected against heat, —as, for example, in milk.[1]

Heat may be used as a disinfectant either as dry heat, steam, or boiling water.

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[1] Vinay, p. 72.

Dry Heat.

Dry heat is used in the laboratory for disinfecting platinum wires, instruments, glass vessels, and cotton wool. We do not, however, use it much for the disinfection of surgical appliances. To obtain reliable results, a temperature of 180° C. for at least thirty minutes is required. Koch ascertained that sporeless bacteria were destroyed by exposure for an hour and a-half to hot air at a temperature slightly exceeding 100° C. The spores of bacilli, such as anthrax, required three hours at 140° C.[1]

The chief spore-bearing bacilli, which surgeons have to fear, are anthrax, tetanus, tubercle, and *bacillus septicus.* We shall see that all these require high temperatures for their destruction. Yersin killed spore-bearing tubercle bacilli in ten minutes with water at a temperature of 70° C. The bacilli were heated in glycerine broth in which they had grown.[2] To kill tubercle bacilli in sputum a temperature of 100° C., acting for at least five minutes, is needed. A much higher degree of dry heat would have been required.

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[1] Koch and Wolfhügel, "Micro-parasites in Disease," *New Sydenham Soc.*, 1886, p. 525.

[2] A method of staining the spores of tubercle bacilli seems to be needed. Its discovery would be a great advance.

All the pyogenic cocci are easier to kill with either dry or moist heat, but *staphylococcus aureus* was only killed by an hour's exposure to a dry heat of 80° C.[1] Sternberg showed that moist heat at 100° C. killed *staphylococcus aureus* in a minute and a-half.

The high temperature which is required to ensure sterility by dry heat is not easy to attain. Moreover, dry heat coagulates blood, pus, or serum in the joints and crevices of instruments. It is possible that the coagulation itself may protect the bacteria from the heat. Then such substances may remain a dangerous source of infection, being rubbed off when the instruments are used.

Moreover, the high temperature of dry heat is harmful to cutting instruments, especially the finer kinds of knives and scissors. Dry heat also requires a special apparatus.

Boiling Water and Steam.

Therefore we use boiling water for the sterilisation of instruments, silk, drainage-tubes, fishing-gut, towels, and utensils. An expensive apparatus is unnecessary. A large enamelled stewing-pan or a fish kettle can be

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[1] Vinay, "Manuel d'Asepsie, la Stérilisation et la Disinfection par Chaleur," Paris, 1890. This work gives much useful information.

purchased for a few shillings. In hospitals where quantities of appliances are required, it may be desirable to provide a large steam steriliser and a large copper pan, but this is chiefly a matter of convenience.

Steam and boiling water are very efficient disinfectants. Kitasato found that tetanus spores bore a temperature of 80° C. for half-an-hour to an hour, but were killed in five minutes in the steam steriliser at 100° C. They were still virulent after ten hours' immersion in 5 per cent. carbolic lotion, but fifteen hours killed them. A solution of perchloride of mercury, one part in one-thousand parts of water, with 5 per cent. of hydrochloric acid, killed them in thirty minutes, although the same strength of perchloride without the acid took three hours.

Koch and his co-workers, Gaffky and Loeffler killed anthrax spores in five minutes with steam at the pressure of the atmosphere. Von Esmarch killed them by the same means in from three to twelve minutes. Vinay says they are killed by steam in two or three minutes, and Sternberg found they did not grow after four minutes' exposure to 100° C.

The spores which Vinay tested were alive after soaking for thirty-seven days in 5 per cent. carbolic lotion.[1]

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[1] Vinay, *loc. cit.*, p. 56.

Some of the spores met with in earth have, however, extraordinary powers of resisting heat. The spores of hay bacillus resisted steam at 100° C. for two hours and a-half,[1] and Courboulès[2] found that a temperature of 120° C. was required to kill the spores of the *bacillus septicus.* This last is, as I have said before, pathogenic for man and animals. Arloing dried and powdered the muscles of animals which had died of anthrax. The virulence of this powder was not destroyed by steam at 100° C. after six hours. It is improbable that the steam reached the anthrax, but the experiment shows how hard it is under certain conditions to disinfect.

In reading the literature of disinfection by heat a good many discordant statements are met with, and the subject seems to require further elucidation.

In difficult circumstances disinfection can only be attained in a short time by using superheated steam. There is no other reliable way of disinfecting clothing, bedding, and the like. In surgery, however, we seldom have to deal with such resistant spores as those of anthrax and gaseous gangrene, nor with such difficult things to disinfect as clothing or bedding. Should,

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[1] Max Gruber, "Notiz über die Widerstandsfähigkeit der Sporen von *Bacillus subtilis* gegen Wasserdampf von 100° C.," *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, 1888, bd. iii., p. 576.

[2] Quoted by Vinay, p. 62.

however, the presence of resistant spores be suspected, extra precautions should be taken.

It is universally acknowledged that the pyogenic cocci, such as *streptococcus pyogenes* and *staphylococcus aureus*, and most of the bacilli met with in wounds, are not more resistant to moist heat than non-spore-bearing anthrax bacilli. Most adult pathogenic germs perish after ten minutes' exposure to 64° C. of moist heat (Vinay). It is, therefore, certain that all non-spore-bearing bacilli and all cocci will be killed by five minutes' sojourn in boiling water. The occasional presence of spores must, however, be taken into consideration. Fifteen minutes in boiling water is enough to kill such as are likely to be met with. A good deal depends, however, upon the thoroughness with which the bacteria or spores are exposed to the heat. For instance, Koch [1] found that "steam generated at the bottom of a deep vessel had a temperature of 70° C. to 78° C., one centimetre above the surface of the boiling water; while in a shallow vessel, in which the steam mixed readily with the air, the temperature at a similar level was 10° C. lower than this." Such a source of error can be overcome by covering the articles with the boiling liquid.

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[1] *Loc. cit.*, "Disinfection by Steam," p. 529.

It is advantageous to add a tea-spoonful of washing soda to each pint of the water used for disinfecting instruments. The soda helps the removal of grease and fat, and prevents the instruments from rusting. Moreover, the addition of the soda renders the boiling-point of the water a little higher, so that disinfection is more certain and rapid.

Dry heat penetrates such substances as silk, towels, glass, or india rubber very slowly, and moist heat takes some time to penetrate them thoroughly. Thus, if a little silk be wound upon a reel for disinfection, time ought to be allowed for penetration; and if much is wound on, a considerable time may be needed before the deeper layers are sterilised.

Before being placed in the steam steriliser or in hot water, towels, or similar things, should be opened out or unrolled. The experiments of Koch, Gaffky, and Loeffler,[1] and of Parsons, clearly showed that heat took a long time to reach the centre of rolls of cloth. A roll of coarse black cloth, 25 c.m. by 8 c.m., was exposed to superheated steam, which in thirty minutes reached 120° C. The temperature at the centre of the roll had not at the end of the half-hour risen to 65° C., but the steam being raised to 126° C., and kept at that tem-

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[1] *New Sydenham Soc.*, 1886, translated by Dr. Whitelegge.

perature for thirty minutes more, the temperature of the cloth rose to 118° C. When first I began to sterilise towels with steam several failures occurred, because we omitted to unfold the towels before putting them in the steriliser. For ordinary purposes the simplest kind of steam steriliser is all that is required. We have obtained excellent results by using one made of copper and arranged like an ordinary potato steamer. I have no doubt but that an ordinary potato steamer would answer perfectly. It is advantageous to have a small hole in the top of the lid of the steriliser for a thermometer. Unless all the air is expelled before use the steam in the sterilising chamber does not attain its highest temperature. But a steam steriliser is by no means essential if an ordinary sauce-pan is at hand.

Before leaving this topic, perhaps I ought to say that cold has hardly any power of disinfection. Sternberg[1] quotes Frisch's experiments in which micrococci and bacilli grew after exposure to –87° C., and Prudden's, in which freezing for sixty-six days did not kill *staphylococcus aureus*.

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[1] *Op. cit.*, p. 145.

CHAPTER XI.

DISINFECTION AND ANTISEPSIS.—*Continued.*

DISINFECTION by chemicals is governed by laws similar to those which govern the action of heat. For instance, cocci and bacilli are more easily killed than spores, and the chemicals act better in simple fluids like water, than in complex fluids, such as milk, blood, pus or sputum.

Complex fluids contain organic or inorganic substances, with which the chemicals combine to form compounds which do no harm to bacteria. It is this that hinders the effects of chloride of zinc, carbolic acid, sublimate, and other chemicals.

The great difference in the resisting powers of non-spore-bearing and spore-bearing bacteria to chemicals is shown by an experiment of Mr. Percy Evans.[1] A solution of sublimate, one part in fifteen thousand parts of distilled water, is said to have killed anthrax *bacilli* in one minute; a solution of one part in one thousand killed *spores* in from three to fifteen minutes.

[1] "Experiments on some Antiseptics and Disinfectants," *Guy's Hosp. Rep.*, London, vol. xlvii., 1890, p. 195, *et seq.*

It is probable that, as Henle suggests, the chemical in the process of disinfection enters into combination with bacteria. Thus a given quantity of chemical can only combine with a given quantity of bacteria.[1] The process also resembles a chemical reaction in being aided by heat.

As Behring[2] points out, the presence of other micro-organisms may help to protect spores from the action of disinfectants.

Generally, a strong solution of a chemical kills bacteria more quickly than one which is weak. But strong solutions may, by coagulating the albumen in the neighbourhood of the bacteria, form a protective barrier.

Bacteria grown upon artificial culture media are not, however, so resistant to heat and chemicals as those growing under what may be called their natural conditions. Van Quens found that staphylococcus and *streptococcus pyogenes* growing in artificial media were killed in a minute and a-half by a temperature of 80°, whilst in pus they took much longer. Tubercle bacilli grown artificially are easier to kill than those in

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[1] "Corrosive Sublimate as a Disinfectant against the *staphylococcus pyogenes aureus*." Abbott, *Johns Hopkins Hosp. Bull.*, Baltimore, vol. ii., No. 12, 1891, p. 50, *et seq.* This paper contains much useful information.

[2] *Loc cit.*, p. 43.

sputum.[1] Abbott says that different specimens of the same species of bacterium possess varying powers of resistance.

Therefore it is not right to think that a disinfectant will be as efficient in practice as it seemed to be in the laboratory. Most laboratory experiments are done with bacteria grown artificially.

I do not propose to describe the effect of oxygen or peroxide of hydrogen upon bacteria, nor the action of the essential oils. Those who are interested in them will find much information in Sternberg's work.

How to Test Chemicals.

Before a chemical is adopted, its properties ought, as far as possible, to be ascertained in the laboratory. A great deal can be learnt by simple experiments with culture media in test tubes. This alone may show that the vaunted specific is a fraud. Should the chemical pass through the ordeal *in vitrio* it should next be submitted to the tests of experimental pathology. Animals are sometimes killed by bacteria which are supposed to have been destroyed by chemicals. The effects of the chemicals upon animals should also, as far as possible, be ascertained. In this way valuable infor-

[1] Vinay, p. 356.

mation may be obtained. For instance, Walthard[1] and Delbet ascertained that suppurative peritonitis did not occur when a certain dose of *staphylococcus pyogenes aureus* was injected into the uninjured peritoneal sac. But they also learnt that it did occur when the surface of the serosa had been injured with solutions of sublimate, or of carbolic acid, or of boracic acid, and so forth. The bearing of this upon abdominal surgery is obvious.

In our pathological laboratory[2] chemicals are usually tested by a modification of Koch's original method. Silk or cotton thread is sterilised with steam or boiling water. Pieces an inch long are soaked for half an hour or an hour in normal saline solution mixed with a virulent culture of anthrax. This ought to have been grown at body temperature for a week, and be full of spores. After having been soaked in anthrax the bits of thread are dried in a sterilised capsule in a warm incubator. They are then soaked in the solution of chemical, and washed in sterile water to remove the chemical. They are then put upon the surface of a culture medium, or dropped into broth, or into a

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[1] "Experimentelle Beitrag zur Kenntniss der Aetiologie der eitrigen Peritonitis nach Laparotomie," *Arch. f. exper. Path. u. Pharmakol.*, Leipzig, 1892, p. 275, *et seq.*

[2] Kanthack and Drysdale, "A Course of Elementary Practical Bacteriology," 1895, p. 126, *et seq.* This is a book full of useful information to those who wish to learn the various methods.

gelatine tube which has been melted to receive them. Finally, the culture is put into the incubator at body temperature. Washing in distilled water is not always enough to remove the chemical, therefore absolute alcohol may be used. Sublimate is best got rid of by agitating the thread for two or three minutes in a 30 per cent. solution of ammonium sulphide.[1] The removal of all the sublimate is of extreme importance. The want of this precaution vitiates many of the earlier observations.

Geppert, to whom we are indebted for valuable work, found that even a 1 per cent. solution of sublimate did not kill anthrax spores after six to twelve minutes' exposure, provided all the sublimate was removed with ammonium sulphide.[2] Perhaps in this experiment the spores are protected by their own investing membrane, or by the albuminous and fatty covering which, as I have said, they are thought to possess. Of course, in all experiments of this kind the usual precautions are taken at each step to avoid contamination. Should foreign bacteria gain an entrance they are easily recognised—as easily as weeds in a garden.

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[1] Behring, "Bekämpfung der Infectionskrankheiten, Infection und Desinfection," Leipzig, 1894, p. 45, *et seq.* This book is full of useful information.

[2] Quoted from Schimmelbusch's "Aseptic Treatment of Wounds." An excellent translation of this book has recently been made by A. T. Rake.

The results must be controlled by other experiments. The threads, for instance, may be inoculated under the skin of a susceptible animal, or mixtures of the chemical with some virulent material may be inserted under the skin. For example, mixtures of tubercle and iodoform, and of anthrax and iodoform, have been tested in this manner.

The inhibitory or antiseptic powers of a chemical are usually ascertained by adding a definite quantity of it to a culture medium, such as gelatine. This is then inoculated with an easily grown microbe, such as *staphylococcus pyogenes aureus.* A control experiment is done at the same time by inoculating a pure culture medium with the same microbe.

Chemicals mixed with nutrient materials can hardly be said to act as disinfectants, and their antiseptic properties are quite trivial. A tube containing ten cubic centimetres of broth was mixed with thirty-two minims of sublimate lotion, the strength of which was one part in one thousand of water. The ordinary skin micrococci grew luxuriantly in this mixture. Their growth was retarded but a few hours. I should estimate that the cocci grew in a mixture of broth and sublimate the strength of which was one part in five thousand. The same kind of experiment was done with carbolic acid. Ten cubic centimetres of broth were

mixed with sixty minims of carbolic lotion, one part of carbolic in twenty parts of water, and inoculated with skin bacteria. A plentiful growth was the result. The carbolic acid merely delayed the growth a few hours.

Doubtless in such experiments as this the chemical is rendered to some extent inert by combining with albumin in the broth. In surgical practice antiseptics and disinfectants are usually spoilt by a similar combination of the chemical with albumin.

After a chemical has been tested in the laboratory we ought, at least, to know whether it kills bacteria or not; how long it requires to kill bacteria; whether it can kill spores; under what conditions it kills bacteria or spores, especially whether it acts in the presence of albumin; to what extent it retards the growth of bacteria; and, finally, whether it may be used without injury to the tissues or without the fear of a toxic effect.

Very few of the antiseptic panaceas which are constantly being introduced fulfil these requirements. But our knowledge of some of the salts of mercury, carbolic acid, and iodoform is fairly complete, and it is to these that I shall confine my remarks.

Effects of Chemicals upon the Tissues, Suppuration.

Before describing those chemicals, however, some-

thing ought to be said upon the oft-debated question as to whether chemicals can cause suppuration.

Scheuerlen's well-known experiments led him to believe that a number of irritating substances, such as croton oil, turpentine, mustard-oil, cantharides, and so forth, could be placed in the cellular tissue of rabbits without causing suppuration. The chemicals were introduced with aseptic precautions in small glass tubes, which were broken when the puncture was healed. These experiments have been repeated and confirmed by Klemperer, Strauss, and others. Ruiys[1] injected diluted turpentine and croton oil into the anterior chamber of the eye without producing pus, although *staphylococcus aureus* caused suppuration which speedily destroyed the whole organ.

Biondi,[2] working upon the same lines as Scheuerlen, arrived at the same conclusion, namely, that chemicals did not cause suppuration. He also found that suppuration did occur round the chemical if *staphylococcus aureus* was simultaneously injected into the veins.

My own experiments done upon rabbits with pure carbolic acid, sterilised croton oil, and sterilised mercury

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[1] Quoted by Senn, "Surgical Bacteriology," p. 94.

[2] "Contributo alla etiologia del pus," *Riforma med.*, Roma, 1886; Abst., *Centralbl. f. Chir.*, Leipzig, 1887, p. 754.

resulted in a limited necrosis of tissues surrounded by a circumscribed area of intense non-progessive inflammation, accompanied by the production of a thick fibrinous exudation or lymph. This was sharply circumscribed and demarcated from the surrounding normal tissues, was confined to the immediate proximity of the chemical, and had no tendency whatever to spread. I found that ptomaines obtained by sterilising cultures of *staphylococcus aureus* acted in the same way. Moreover I have observed that if these animals were injected with carmine gelatine when the lymph caused by chemicals was a week or ten days old, a delicate network of vessels had begun to penetrate the lymph; or, in other words, that the aseptic lymph caused by strong chemicals was capable of organisation. This has hitherto been strangely overlooked.

On the other hand, Grawitz and de Bary[1] say that turpentine, nitrate of silver, and ammonia cause pus-production if injected beneath the skin of dogs and some other animals, but I have not repeated these experiments. Large quantities of the chemical are required, and it is to be noted that the result is only a local lesion. Dubler,[2] whose work is very exhaustive, also

[1] "Ueber die Ursachen der subcutanen Entzundung und Eiterung," *Virchow's Archiv*, 1887, p. 97, *et seq.*

[2] "Ein Beitrag zur Lehre von der Eiterung," Basel, 1890.

believes that the acute inflammation and necrosis caused by chemicals is followed by pus-formation. In Watson Cheyne's[1] experiments with sterilised croton oil suppuration occurred, but bacteria were found in most instances.

These contradictory results may depend upon differences in the kind of animals employed, upon the kind of chemical, upon the strength of the solutions which were applied, or upon the manner of their application; but I cannot help thinking that much depends upon our conception of the properties of pus. If there was only one kind of pus the matter would be simple. Unfortunately there are many kinds, with various properties and significances, and the result of the action of various causes.

Pus.

By some the different kinds of pus have been classified according to their physical characters, and called laudable when smooth, opaque, creamy, and yellowish white, and without the odour of putrefaction; sanious when tinged with blood; ichorous when thin and watery; curdy when containing flakes; muco-pus

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[1] "Antiseptic Surgery," p. 251.

when diluted with mucus; and so forth.[1] This rather quaint classification, which was the best that could be made in former times, neither takes into consideration nor affords any clue to the biological and chemical properties of pus. Yet these are of transcendent importance. For instance, pus which contains *staphylococcus aureus* has properties different from that which contains *streptococcus pyogenes,* and is usually associated with a different morbid process; and each of these, again, is distinct from that which contains tubercle bacilli. Nevertheless the physical resemblance of these various kinds of pus is so close that they could not be discriminated by it alone.

Thus the physical characters of pus (and I might add of other fluids) afford hardly any clue to its biological properties. These can only be ascertained by microscopical examination, by cultivation, and by experiment. The microscopical examination may betray the presence of bacteria; cultivations may disclose their identity, and experiments their pathogenic properties. None of these three methods can be relied upon by itself alone.

Occasionally the microscopical examination may afford a high degree of certainty as to the biological

[1] Erichsen, "Science and Art of Surgery," 9th edition, 1888, vol. i., p. 230.

properties of pus. There could be little doubt about the identity of bacilli which had the characteristic staining reaction and appearances of tubercle bacilli; or which had the sharply cut-off, square-looking ends, and large dimensions, of anthrax bacilli. But these are at present rather isolated instances of the value of the microscopical examination of pus. But when that method fails, then cultures may disclose bacteria which could not be seen with the microscope. Also plate cultures may enable us to separate several kinds. But many bacteria grow so badly that cultures are of little value for their detection. The bacillus of tetanus, of tubercle, of malignant œdema, and actinomyces are examples. Attempts to grow these usually fail, because other bacteria grow and overwhelm them, or because the media are unsuitable.

When bacteria can neither be seen with the microscope nor grown in cultures, their presence may be ascertained by inoculation experiments upon animals. Tubercle is frequently diagnosed in this way. But it is to be remembered that too much should not be inferred in the event of failure, because the animals used for the experiment may have been immune.

The various sepsins, toxins, or ptomaines which some kinds of pus contain, and which are manufactured by

bacteria, are obviously of great importance, but their presence is usually ignored in the diagnosis of pus. Tests which would easily demonstrate their presence would be invaluable.

Thus the inflammation excited by a chemical is *non-progressive*, and strictly confined to the area to which it was applied, because the chemical has no inherent power of increasing. Bacteria, on the other hand, excite a progressive inflammation, because they multiply and grow into fresh tissues. The degree of inflammation which a chemical causes depends upon its strength, quantity, quality, and mode of application. For instance, ammonia[1] diffuses and penetrates the tissues, whilst carbolic acid or metallic mercury remain where they were placed. The influence of the strength and quantity of chemicals, and of their varying effects upon skin, mucous membranes, tissues, special organs, and so forth, is too well known to need to be mentioned.

The way in which irritating substances are introduced is of moment. Five per cent. chloride of zinc solution injected under the skin is often followed by pus-formation, the skin itself having undergone changes

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[1] Grawitz u. de Bary, "Ueber die Ursachen der subcutanen Entzundung und Eiterung," *Virchow's Archiv*, 1887.

which permit infection from the exterior; injected into muscles a coagulation of albumin results, but the coagulum is soon absorbed.[1] It is also well known that in the treatment of syphilis by injections of solutions of perchloride of mercury suppuration is apt to occur unless the injection is made into the substance of the muscles.

Thus we conclude that dilute chemicals cannot cause progressive suppuration or produce infective pus. Some chemicals, however, may, when very concentrated, cause non-progressive circumscribed inflammation, the product of which may be a non-infective fluid with the physical and microscopical characters of pus. This fluid is, however, more often spoken of than seen. Infective pus is a reproach to the surgeon, and the occurrence of this non-infective fluid, which may be caused by chemicals, ought not to be affirmed until appropriate bacteriological tests have been applied.

Strange as it may seem, pus, the product of bacterial activity, is not a favourable medium for them to live in.

It has been ascertained by Grawitz[2] that sterilised

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[1] *Loc. cit.*, pp. 82-83.

[2] "Beitrag zur Theorie der Eiterung," *Virchow's Archiv*, bd. cxvi., p. 116.

pus has a deleterious effect upon some kinds of bacteria. When pyogenic cocci are mixed with such pus they rapidly diminish in numbers, and in ten days none can be found. Eichel found that pyogenic cocci soon died in the pus of acute abscesses. These experiments have been confirmed by Dr. F. W. Andrewes,[1] who found that pyogenic cocci and anthrax died a few hours after having been introduced into pus. On the other hand, pus was an excellent culture fluid for the bacillus of diphtheria and for the *bacillus prodigiosus*. The last is a remarkable microbe, which is easy to obtain and cultivate, grows with great rapidity, and is supposed to account for the phenomena of bleeding bread and bleeding host (Flügge).

It used to be taught that when a foreign body entered the tissues it caused inflammation and suppuration, and was extruded. Now it is recognised that the tissues tolerate sterile foreign bodies. Those which cause suppuration are septic, a fact which was hidden from the older teachers. Grawitz[2] ascertained that the peritoneum would tolerate aseptic wool, linen, and sponge, but that these caused suppuration when small quantities of *staphylococcus pyogenes aureus* were added. We have already seen that small doses of *staphylococcus*

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[1] *Rep. Med. Off. Privy Council*, London, 1893.

[2] *Loc. cit.*, p. 12, *et seq.*

aureus do not cause peritonitis when the peritoneum is uninjured or unoccupied by blood clot or foreign bodies. In operations such as those for the radical cure of hernia the tissues tolerate quantities of silk so long as it is sterile.

CHAPTER XII.

SUBLIMATE.[1]

The most discordant statements are made about the properties of chemicals which are in everyday use. Therefore I only propose to refer briefly to mercuric perchloride and mercuric biniodide, to carbolic acid, and to iodoform. It will be seen that, although these are probably the best we have, nevertheless they are all most inefficacious disinfectants, but fair antiseptics.

Perchloride of mercury.—Koch gave a great impulse to the use of mercuric perchloride. Writing in 1885, he said that it destroys the most resistant organisms in a few minutes by a single application of a highly dilute solution (1 to 1000, or even 1 to 5000). With longer exposure it only begins to be unreliable when diluted beyond 1 to 20,000. Most of his experiments were done with anthrax spores or earth spores. Indeed, according to Koch, three parts of sublimate in a million parts of water arrests the development of anthrax

[1] *Syn.*, or perchloride of mercury.

bacilli, but does not kill them.[1] But later researches have shaken our faith in sublimate.

According to Warrikoff[2] and others, Koch greatly under-estimated the resistance of anthrax bacilli and of anthrax spores.

Koch experimented with anthrax threads which were soaked in the sublimate solution, and then washed with water or alcohol. It is likely, therefore, that enough of the chemical was left to mar the result. Geppert,[3] whose papers are very valuable, got rid of all the sublimate from his threads by dipping them, as I have already described, in a solution of sulphide of ammonium. He began by ascertaining that one part of sublimate in one thousand parts of water *seemed* to kill anthrax spores in three minutes if no sulphide of ammonium was used; the spores did not germinate when placed upon culture media. But this was only an apparent death, because when all the sublimate was removed with sulphide of ammonium, Geppert found that the spores were in reality alive, even after having been exposed to one in one thousand sublimate for twenty minutes, and in some cases, in truth, after

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[1] *New Sydenham Soc.*, translated by Dr. Whitelegge, 1886, p. 513.

[2] Quoted by Cornil et Babes, "Les Bactéries," tome i, p. 50.

[3] "Zur Lehre von den Antiseptics," *Berl. klin. Wchnschr.*, 1889, Nos. 36 and 37; also "Ueber desinficirende Mittel und Methoden," *loc. cit.*, 1890, p. 246 *et seq.*

twenty-four hours. One per cent. solution of sublimate did not come well out of Geppert's tests. Spores still grew after six to twelve minutes' exposure to that strength. Moreover, the spores were not robbed of their pathogenic properties after several hours' exposure. Nissen, by using Geppert's methods, found that spores were alive after four hours in a 1 per cent. solution of sublimate.

Dr. Kanthack[1] is accustomed to grow anthrax from threads soaked for four hours in a 1 in 1000 solution of perchloride of mercury, provided that all of the chemical is removed with ammonium sulphide.

Behring[2] states that anthrax spores killed mice after they had been thirty minutes in a solution of sublimate one part in one thousand. After four hours in the same strength of sublimate the spores were still alive, but had lost their virulence. A 1 per cent. solution of sublimate killed anthrax spores in twenty minutes.

We have already seen that a solution of one part of sublimate in one thousand parts of water, with the addition of 5 per cent. of hydrochloric acid, took thirty minutes to kill tetanus spores; without the acid the same solution took from three hours to three minutes; the variation being, perhaps, accounted for

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[1] "Practical Bacteriology," p. 128.

[2] *Op. cit.*, p. 46.

by the acknowledged difference which exists in the resisting powers of different samples of spores.

The experiments of Tarnier and Vignal[1] show that the susceptibility of *staphylococcus aureus* to the action of solutions of mercuric perchloride and of carbolic acid is the same as that of *streptococcus pyogenes.* A solution of 1 part of sublimate to 1000 parts of water killed *aureus* in two minutes, but carbolic lotion 1 part in 100 parts required from fifteen to seventeen minutes.

Von Lingelsheim says that one part of perchloride of mercury in two thousand five hundred parts of water took two hours to kill *streptococcus pyogenes.* One part of carbolic acid in three hundred parts of water required the same time.

Christmas seems to have been more successful with *staphylococcus aureus* by using a much larger proportion of sublimate.[2]

Gärtner and Flügge[3] seem to have had better results with non-spore-bearing anthrax bacilli and a number of pyogenic cocci and streptococci; one in one thousand sublimate solution seems to have killed these bacteria in eight seconds. But Gärtner and Flügge

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[1] Tarnier et Vignal, *Arch. de méd. expér. et d'anat. path.*, Paris, July 1890.

[2] "Sur quelques Mélanges antiseptiques," *Ann. de l'Inst. Pasteur*, Paris, 1892, p. 279.

[3] Quoted by Flügge, *loc. cit.*, p. 667.

did not use sulphide of ammonium, and nothing is said about control experiments upon animals.

Flügge[1] claims that a solution of sublimate one in five thousand kills all spores in some hours ; a solution one in one thousand does the same in a few minutes.

But although a 1 per cent. solution of sublimate takes so long to kill spores, yet a much smaller quantity seems enough to stop the growth of bacteria in various fluids. De la Croix found that the development of bacteria ceased in meat infusion when he added one part of sublimate to thirty thousand two hundred and eight parts of infusion.[2]

Miquel[3] prevented the development of bacteria in meat infusion by adding to it one part of sublimate to fourteen thousand three hundred parts.

Sublimate is a treacherous disinfectant and antiseptic, because, as Laplace[4] and others have shown, it combines with albumin to form an insoluble albuminate of mercury which is inert. Laplace thought that this was prevented by the addition of tartaric acid to the solution of the mercuric salt. His prescription was 1 part of sublimate, 5 parts of tartaric acid, and 1000 parts of water.

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[1] Flügge, *loc. cit.*, p. 670. [2] Flügge, *loc. cit.*, p. 657, *et seq.*
[3] Flügge, *loc. cit.*, p. 652.
[4] *Deutsche med. Wchnschr.*, Leipzig, 1887, No. 40, p. 866.

Behring,[1] however, found that this solution took ten minutes to kill staphylococci and streptococci in the presence of serum-albumin. He also says that it did not mix well with pus, although it disinfected some which contained *aureus* and streptococci in fifteen minutes.

Abbott[2] agrees with Henle that sublimate combines chemically with the bacteria, and therefore that a given quantity of the drug can only kill a given number of bacteria. If albumin is present, the bichloride combines with it instead of combining with the bacteria, and thus becomes quite useless. Abbott found that in watery solutions *staphylococcus aureus* was rapidly killed by 1—1000 sublimate, although solutions in broth were only killed with extreme difficulty and after many minutes. Much depended upon the purity of the drug.

Percy Evans,[3] who experimented upon *aureus* in broth, also got most uncertain results with sublimate. The bacteria were only killed when the drug had been added to the broth in the proportion of 1 to 150,

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[1] Behring, "Ueber Quecksilbersublimat in eiweisshaltigen Füssigkeiten," *Centralbl. f. Bakteriol. u. Parasitenk.*, 1888, Jena, bd. iii., pp. 27 and 64.

[2] "Corrosive Sublimate as a Disinfectant against the *staphylococcus pyogenes aureus*," *Johns Hopkins Hosp. Bull.*, Baltimore, vol. ii., No. 12, April 1891.

[3] "Experiments on some Antiseptics and Disinfectants," *Guy's Hosp. Rep.*, London, vol. xlvii., 1890, p. 195, *et seq.*

and then it took a quarter of an hour to act. However, it inhibited the growth of *aureus* when in the proportion of 1 to 50,000.

Various other attempts have been made to prevent sublimate combining with albumin, and thus becoming inert. Sir Joseph Lister used to recommend a sero-sublimate which was made by mixing sublimate with the serum of horses' blood. Of late this has been replaced with *sal-alembroth.* This is a double chloride of mercury and ammonium—an ammonio-mercuric chloride. It is made by mixing solutions of sublimate and chloride of ammonium together and evaporating. Every three parts contain two parts of sublimate. It is a powerful disinfectant, and does not combine with albumin so quickly as pure sublimate. It is, however, in my experience excessively irritating when in contact with the skin or tissues for any length of time. The blue alembroth gauze contains one per cent. of sal-alembroth and the blue wool two per cent., which readily explains their evil effects upon the skin.

Solutions of sublimate in water often become cloudy, owing to the formation of a precipitate which is said by Angerer [1] and Meyer [2] to be an oxychloride. Doubtless

[1] O. Angerer, "Bemerkungen über die Herstellung antiseptischer Sublimatlösungen," *Centralbl. f. Chir.*, Leipzig, 1887, p. 121.

[2] "Versuche über die Haltbarkeit von Sublimatlösungen," *Centralbl. f. Chir.*, Leipzig, 1887, p. 448.

this milkiness detracts from the efficacy of the solution, but its occurrence is said to be prevented by the addition of common salt in a proportion equal to or double that of the sublimate. Tartaric acid is supposed to have the same effect. Mr. Parsons, our apothecary, has with great kindness told me how to prepare solutions of perchloride of mercury, biniodide of mercury, and of carbolic acid. His directions will be found practical and economical, especially where quantities are required. In the dispensary a stock solution of perchloride of mercury in glycerine is kept for making solutions of different strengths. The stock solution is made by reducing one part of pure perchloride to a fine powder, which is then triturated in a mortar with twelve parts of glycerine. Next, this mixture is put in a water-bath at a temperature of 180° F., and stirred with a glass rod until all the perchloride is dissolved. If the heat be continued after this the solution becomes turbid, and deposits on cooling. A deposit also forms if the chemicals are impure, or if metal utensils are used. To make perchloride of mercury lotion a given quantity of the glycerine solution is added to distilled water. Tap water generally becomes cloudy for the reasons which have just been mentioned.

For midwifery purposes powders of perchloride of mercury are made by mixing together one part of

perchloride of mercury, five parts of dried tartaric acid, and one part of cochineal. The colouring matter is merely to make the powers distinctive. For private practice Angerer's tabloids of sublimate and chloride of sodium are very convenient. One of them added to a pint of water dissolves at once, and gives a solution of one part in one thousand.

It is clear from the above that sublimate has many disadvantages.

Biniodide of mercury.—Many of the objections to it can be met by using biniodide of mercury, and during the last two or three years I have used it instead of the perchloride, because it seems to have the following advantages:—First, it does not seem to combine with albumin. At all events, no visible combination takes place. When a wound is washed with a solution of one part in one thousand parts of water it does not acquire that pickled appearance which carbolic acid and sublimate impart, but looks the same as if it had merely been washed with water. Moreover, when biniodide lotion is mixed with blood, no precipitation occurs. The mixture does not become opaque with coagulated albumin, but remains clear and translucent, except when the blood is in excess, and there is no precipitate. For this reason the sisters and nurses prefer the biniodide lotion for rinsing the soiled sponges. The

non-coagulation of albumin also makes the biniodide of mercury a safer disinfectant and antiseptic for a variety of purposes, especially for washing out septic cavities. When such a one is irrigated with sublimate, a quantity of albuminate of mercury is of necessity left behind. This source of danger does not occur with biniodide. For similar reasons the penetrating powers of biniodide are probably greater than those of sublimate or of carbolic acid. The albuminous compounds which these chemicals form is a barrier against the further action of the drug.

The biniodide was used more than twenty years ago by Panas. Its use has been warmly advocated by Illingworth and others. Sternberg's investigations give it a decided superiority.[1] Illingworth[2] says that Woodhead has conclusively proved its greater efficiency. It is also claimed for biniodide that it is less poisonous than the perchloride of mercury. This may be because, as I have said, after a wound or cavity has been washed with biniodide, a quantity of albuminate of mercury does not remain behind.

Various antiseptics are being continually tested by Dr. Kanthack in our laboratory, and from time to time I have seen the results. Kanthack admits that the

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[1] *Loc. cit.*, p. 185.

[2] *Med. Times and Gaz.*, London, 1894, p. 65.

biniodide is the most efficient disinfectant he has tried.[1] It has almost twice the germicidal value of sublimate. Miquel also gives biniodide of mercury an antiseptic value which is twice as great as sublimate.[2] I have had much better results in the disinfection of the skin since I began to use it, and wounds have certainly done better.

Solutions of biniodide of mercury are very easy to prepare. The red powder may be bought of the chemist. It is insoluble in water, but soluble in the presence of rather more than an equal quantity of iodide of potassium or of iodide of sodium. Therefore, to make a lotion, the biniodide is shaken up with distilled water, and rather more than an equal weight of iodide of potassium or of iodide of sodium is added. It is advantageous to add a little more iodide if hard water is used instead of distilled water; in any case an excess of the iodide can do no harm. If no biniodide powder is at hand, a lotion is easily made by taking a one in one thousand solution of sublimate and adding iodide of potassium or of sodium to it. At first the red iodide is precipitated, but this is quickly dissolved by the iodide, and a clear watery solution is the result. It is convenient to keep a stock solution of one part of biniodide in fifty parts of distilled water. For private practice the small soloids or lozenges

[1] "Practical Bacteriology," p. 128.

[2] Quoted by Sternberg, *op. cit.*, p. 184.

of biniodide are useful. It is important to see that these are made of a convenient size, so that one soloid makes, say, a pint of lotion, the strength of which is one in one thousand. Also the soloids ought to dissolve at once in tepid water. Some of the lozenges which are sold are quite untrustworthy on account of their insolubility.

I now use biniodide throughout the operation for rinsing out the sponges, for the occasional flushing of the wound, and for the continuous bathing of the hands of the operator and of his assistant. All of these have, of course, been previously disinfected in the way I shall describe, and the biniodide is used as an antiseptic. For this purpose it is most efficient. A solution of one part in five hundred parts of rectified or methylated spirit is used to disinfect the skin.

CHAPTER XIII

CARBOLIC ACID.

Experimenters seem to make the most contradictory statements concerning carbolic acid. According to Evans,[1] a 2 per cent. solution of carbolic acid is said by one observer to kill *staphylococcus aureus* in eight seconds, whilst another asserts that this is only achieved after fifteen minutes. Mr. Evans' own results are almost the same, for he found that 1 in 40 took fifteen minutes to kill *aureus* in broth.

Carbolic acid came badly out of Geppert's tests. Anthrax spores, after lying for thirty-eight days in a 7 per cent. solution, grew on agar-agar, and killed guinea-pigs.[2]

Christmas[3] says anthrax spores may be kept in 20 per cent. carbolic acid for a month without the least alteration. Even 50 per cent. carbolic took eight days to kill anthrax spores.

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[1] *Guy's Hosp. Rep.*, London, vol. xlvii., 1890, p. 245.

[2] "Ueber Desinficirende Mittel und Methoden," *Berl. klin. Wchnschr.*, 1890, p. 247.

[3] *Loc. cit.*, p. 276.

Gärtner and Flügge[1] seem to have obtained the same exceptionally favourable results with carbolic acid as they did with sublimate. They claim that a 3 per cent. solution killed non-spore-bearing anthrax and a variety of pyogenic cocci and streptococci in eight seconds. But Vinay found that anthrax spores were alive after soaking for thirty-seven days in 5 per cent. carbolic lotion. The effects of carbolic acid upon the typhoid bacillus is also very slight. It grows well in the presence of considerable quantities (·4 per cent.). Indeed, this peculiarity is used to separate the typhoid bacillus from other kinds.

Schill and Fischer[2] say that sputum containing tubercle bacilli and their spores is disinfected by an equal volume of 5 per cent. carbolic lotion in twenty-four hours. A one in five hundred solution of sublimate was not efficient in the same time and in the same quantity. I have already pointed out that disinfection depends both upon the chemical which is used and upon the microbe which is acted upon by it, as well as the conditions under which the chemical acts.

Carbolic acid kills spores much more quickly when it is mixed with hydrochloric acid. In this respect it

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[1] Flügge, *loc. cit.*, p. 668.

[2] Quoted in article "On Disinfection," *Quain's Dictionary of Medicine*, edition 1894, p. 525.

resembles sublimate. A 1 per cent. solution of carbolic acid in water took thirty days to destroy anthrax spores. A 1 per cent. solution of hydrochloric acid took as long. A mixed solution of 2 per cent. carbolic acid and 1 per cent. of hydrochloric acid killed the spores in seven days; 4 per cent. of carbolic acid and 2 of hydrochloric acid destroyed spores in less than an hour. The carbolic acid alone required at least twelve days.[1]

Dr. W. Black Jones tested the relative disinfecting properties of sublimate, biniodide of mercury, and of carbolic acid. Sterilised silk threads were infected by soaking them in pus discharged from a necrosis of the femur. These were disinfected in a minute by an aqueous solution of sublimate, one part in five hundred, and by an aqueous solution of biniodide, one part in one thousand. A solution of carbolic acid, one part in twenty of water, did not disinfect in the same time. Solutions of the same chemicals in glycerine or in alcohol were much less efficacious. Mr. Furnivall obtained the same results—mixtures of carbolic acid with alcohol and with glycerine, one part in twenty, did not disinfect in ten minutes. Glycerine also seemed to diminish the disinfecting properties of

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[1] Laplace, quoted by Sternberg.

biniodide and perchloride of mercury, but not to the same extent.

Carbolic oil is inert. Anthrax spores were absolutely unaffected by lying for 110 days in a 5 per cent. solution of carbolic acid in oil. Even anthrax bacilli were not more affected by the same solution than by pure oil.[1] Mixtures of carbolic acid and glycerine are also inert until diluted with water.

Some of Mr. Furnivall's silk threads were left for ten days in a 5 per cent. solution of carbolic acid in glycerine. At the end of that time, pyogenic cocci grew freely when the threads were put upon an agar-agar plate.

The carbolic acid which we use comes in beautiful snow-white crystals, which melt at 40° C. (104° F.), and have very little odour.

Although my own hands are easily injured by carbolic acid, I have never known this quality cause an eczema. The crystals of carbolic acid are made into a solution by melting them in a water bath. The water is then added and the mixture stirred. In winter, when the temperature is low, some glycerine is added to prevent recrystallisation. The strongest solution which can be made at 56° F. is one part of carbolic acid

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[1] Koch, "On Disinfection," *New Sydenham Soc.*, "Microparasites and Disease," 1886, p. 503.

to fifteen of water, but at 95° F. one part of carbolic is soluble in twelve of water. With glycerine it is possible to obtain a solution of one part of carbolic acid to two of glycerine. The carbolic acid is very apt to crystallise out of its solutions when the temperature falls below a certain point. This also occurs when the solutions are poured into cold trays or vessels. The crystals which form are not at once redissolved by warm water, and are, Mr. Parsons suggests, the cause of the eczema which sometimes troubles operators.

It is most important to use pure carbolic acid. The commoner kinds are much more irritating and poisonous. The pharmacopœial standard of purity is too low. It allows a melting-point of 33° C. instead of 40° C.[1]

I always use 5 per cent. carbolic gauze as a dressing next to the wound. There are many ways of preparing this material. One of the main objections to this admirable dressing is that after a few days it dries into a hard cake, which is apt to be stiff and uncomfortable. On the other hand, it seems to be sufficiently absorbing and quite unirritating, although it contains 5 per cent. of carbolic acid. That which we use is prepared from a formula of Sir Joseph Lister's, by passing sterilised muslin through a melted mixture of

[1] M. Charteris, "Notes on Carbolic Acid," *Brit. Med. Journ.*, London, 31st December 1892, p. 1424.

paraffin four parts, resin four parts, and carbolic acid one part. After the excess of this mixture has been squeezed out, the gauze or muslin ought to contain in its interstices 5 per cent. of carbolic acid. Some manufacturers add a small proportion of castor oil to make it softer.

Carbolic acid seems to have such slight disinfecting properties that I seldom use it for that purpose. Even pure carbolic acid has not given me good results. On the other hand, carbolic acid is an efficient antiseptic, and dilute solutions seem to have little action upon cutting instruments. Therefore I use a 5 per cent. solution to keep sponges in after they have been disinfected by other means. Also a $2\frac{1}{2}$ or 2 per cent. solution is used for the immersion of the instruments, silk, fishing gut, and drainage tube during the operation.

CHAPTER XIV.

IODOFORM.

Few drugs have been so extravagantly praised a iodoform,[1] and hence, perhaps, there has been a corresponding reaction against its use. However, there can be no doubt but that for certain purposes it is a valuable remedy. Its use in our hospital dates back to the late Dr. Greenhalgh, who was for many years physician-accoucheur. Iodoform (CHI_3) is made by the action of iodine on a hot solution of carbonate of soda in diluted alcohol. It is sold either as an impalpable precipitated powder (Iodoformum præcipitatum) or as a crystalline powder. The former is, perhaps, most liable to adulteration, and therefore it is best to buy the crystals, which may be either used as they are or after trituration in a mortar.

Iodoform is quite insoluble in water, in dilute acids, or dilute alkalies ; it is fairly soluble in alcohol, ether, chloroform, benzine, ethereal and fatty oils, and

[1] *E.g.*, von Nussbaum, "Leitfaden zur antiseptischen Wundbehandlung," fifth edition, 1887, p. 82, *et seq.*

bisulphide of carbon. It is decomposed by strong acids and alkalies and alcoholic solution of caustic potash. It is also decomposed by sunlight. It contains a large proportion of iodine, twenty-nine thirtieths of its weight.

In 1886 Heyn and Rovsing[1] showed that iodoform did not kill cultures of pyogenic cocci, pneumococcus, or *bacillus subtilis.* It had hardly any effect upon their growth or their pathogenic properties. They concluded, therefore, that iodoform was useless as an antiseptic or disinfectant, and might even cause infection. This is clearly going too far. De Ruyter[2] observed that some of his samples of iodoform contained moulds, but never any pathogenic bacteria. He also found that iodoform had no action outside the body. When dusted upon plates, it merely restrained the growth of bacteria by preventing the supply of air, and by being a mechanical obstacle. It effectually prevented plates of nutritive material dusted with it from becoming infected by the air, but starch had the same effect. When a wound was rubbed with iodoform, and then inoculated with pathogenic microbes, the animals died, but more slowly than usual. Pathogenic bacteria and materials, such as

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[1] *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, 1887, bd. i., p. 120.

[2] Gustav de Ruyter, "Zur Iodoformfrage," *Arch. f. klin. Chir.*, Berlin, 1887, p. 213, *et seq.*

the organs of animals dead of anthrax, had their virulence lessened by being mixed with iodoform. Iodoform was decomposed, it is said, when mixed with pus, iodine being liberated, but I have been unable to confirm this observation. Iodoform is not a reliable disinfectant, except when mixed with ether and alcohol in the proportion of one part of iodoform to two parts of ether and eight of alcohol. This mixture is said to contain, after exposure to light, 1 per cent. of free iodine.

I have given up using made-up solutions of iodoform collodion. After a while they develop pungent acrid vapours, which are most irritating. It is quite easy to apply the collodion to the wound, and then dust it when drying with the iodoform powder. This is a most valuable dressing for wounds of the face, or in places where the dressing which I will describe presently cannot be applied.

Iodoform has also been said to have an especial value for the destruction of tubercle bacilli, but it is probable that this has been exaggerated. Rovsing[1] says that portions of tubercular organs retained their infective properties after having been triturated with four or five times their bulk of iodoform powder. On the other hand, de Ruyter found that tubercle bacilli refused to grow

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[1] "Hat das Iodoform eine Antituberculöse Wirkung, eine Experimentelle Untersuchung," *Fortschr. d. Med.*, Berlin, 1887, p. 257.

upon media to which a little iodoform had been added.

According to Yersin[1] cultures of tubercle bacilli are killed by iodoform in five minutes.

Laboratory experiments show that some mixtures of iodoform are almost as inert as the powder. Heyn and Rovsing[2] were unable to kill moulds, a white micrococcus, *staphylococcus pyogenes aureus*, pneumococcus, and *bacillus subtilis* with a 4 per cent. solution of iodoform in olive oil. De Ruyter found that 10 per cent. solutions of iodoform in glycerine or bisulphide of carbon had feeble antiseptic properties, and contained hardly any free iodine.

Tilanus[3] did not get good results with iodoform. He grew various bacteria, including *staphylococcus aureus* and *micrococcus putridus*, on media containing iodoform. I have grown *aureus* luxuriantly in broth which contained a large percentage of iodoform.

Laboratory experiments do not altogether account for the efficient service which iodoform renders in the wards. For instance, I found[4] that when iodoform powder is

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[1] A. Yersin, "De l'Action de quelques Antiseptiques et de la Chaleur sur le Bacille de la Tuberculose," *Ann. d. l'Inst. Pasteur*, Paris, 1888, No. 2, p. 60, *et seq.*

[2] Heyn and Rovsing, *Centralbl. f. Bakteriol. u. Parasitenk.*, Jena, bd. i., 1887, p. 120.

[3] B. Tilanus, "Ist Iodoform ein Antisepticum?" *München. med. Wchnschr.*, 1887, No. 17.

[4] *Brit. Med. Journ.*, London, 28th May 1892.

dusted upon colonies of *staphylococcus aureus* or *albus*, or of *staphylococcus epidermidis albus*, it does not kill them, but merely arrests their growth. At the same time the dusting prevents the media from becoming infected when exposed to the atmosphere, but sugar and starch are almost equally effective in this respect. Further, the addition of small quantities of iodoform powder to broth does not spoil it for growing the ordinary pyogenic cocci. Added to ordinary water iodoform reduced the number of bacteria, but only because it helped to precipitate them.[1]

I was at one time inclined to think that the iodoform which was dusted upon the skin was more potent in destroying the bacilli than the cocci. As I have already said, cocci are found oftener than bacilli in antiseptic wounds. But with Dr. Blackwell's help it was easily ascertained that a mixed plate culture of bacilli and cocci of the skin, when inoculated into secondary cultures, grew both kinds equally well for some days after it had been dusted with iodoform.

Although iodoform has such feeble action upon bacteria and spores, nevertheless, as Behring[2] has shown, it can neutralise their toxins or ptomaines. That observer ascertained that Brieger's cadaverin

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[1] Gustav de Ruyter, "Zur Iodoformfrage," *Arch. f. klin. Chir.*, Berlin, 1887, p. 213, *et seq.*

[2] "Infection and Disinfection," p. 105.

caused suppuration when introduced pure into the cellular tissue of animals. But a mixture of iodoform and cadaverin did not have such an effcct. Neisser, Lanz, and Flach have arrived at similar conclusions.[1]

Von Nussbaum,[2] who seems an enthusiastic advocate of iodoform, says that in many cases it far exceeds carbolic acid, sublimate, chlorine water, or any of the antiseptics which he knows. He recommends it for the treatment of foul cavities and sinuses, especially those connected with caries and necrosis of bone. His prescription is as follows:—Iodoform 10 parts, æther. sulph. 70 parts, distilled water 200 parts. This is to be thoroughly squirted into every crevice of the foul locality. He also recommends it for slowly healing ulcers, cancers, venereal sores, and for use in aural surgery.

As the disinfection of the human skin is still an uncertain process,[3] I am accustomed to use finely powdered crystals of iodoform to dust all the skin which underlies the dressing, and into any folds, chinks, or crevices in the neighbourhood. I seldom or never dust it into a wound, bccausc it is apt to remain as an insoluble foreign

[1] Quoted by Sehwartz, "La Pratique de l'Asepsie et de l'Antisepsie," p. 34.

[2] "Leitfaden zur antiseptischen Wundbehandlung," Stuttgart, 1887.

[3] During the past year we have made a decided improvement in the disinfection of the skin. With the one in five hundred solution of biniodide and spirit, disinfeetion is the rule and not the exception.

body and prevent repair. Iodoform powder is of the greatest use in preventing blistering of the skin beneath dressings. We habitually leave our dressings untouched for eight or ten days. It is also of especial value as an application should any blistering or dermatitis have been caused by a dressing.

The power of iodoform to keep a wound aseptic, and one of the conditions under which it is of peculiar utility, was illustrated by the following:—A girl, aged seventeen, had an incomplete right inguinal hernia, for which I performed the operation of radical cure. After the patient had had a hot bath the skin was prepared by Mr. Murrell by shaving, scrubbing with soft soap and hot water, washing with 5 per cent. carbolic lotion, and saturating with sublimate glycerine 1—2000, with a dressing of which it was also covered. As I was called away by an emergency, this dressing was left on for forty-eight hours, and when it was removed the skin was blistered, and there was also a crop of scattered pustules. Forty-eight hours after the operation the skin around the wound was red and blistered, the bullæ being filled with thin turbid fluid.[1] Cultures inoculated from these remained sterile, as did others which were inoculated from the wound. The whole area was thickly dusted with

[1] Mr. W. H. Pollard, in his very clear notes, calls this fluid purulent.

iodoform and covered with iodoform gauze. Next day the whole area had become dry, and more iodoform was dusted on, and the same dressing left in place. On the twelfth day it was all removed, the wound being healed. Cultures inoculated from the line of the wound and with a suture underwent no change. The case ran a typical aseptic course, the highest temperature having been 99° F.

If any one were to claim that this was an instance of suppuration, without infection, it would, I confess, be hard to prove the contrary. However, the process by which the turbid fluid was produced by the denuded skin was in reality a catarrhal one, and I am aware of no researches having been made to show the exact relationship of bacteria to the catarrhs. The evidence is strong that some, especially gonorrhœa, are caused by bacteria

In young children and old people iodoform is prone to produce poisoning, especially if it be put into wounds or cavities.

Nussbaum[1] describes three degrees of iodoform poisoning:—in the first there is melancholy and loss of appetite, with a constant smell of iodoform in the nostrils; in the second, hallucinations and delirium,

[1] "Leitfaden zur antiseptischen Wundbehandlung," Stuttgart, 1887, p. 85, *et seq.*

all nourishment being refused; in the third there is mania, followed by stupor and collapse. The very young and the very old seem most predisposed to iodoform poisoning, which, however, is with difficulty discriminated from the sepsis which often accompanies it.

One of the most important symptoms of iodoform poisoning is the appearance of free iodine in the urine. This can be ascertained by the usual tests for iodine.[1] Doubtless inquiry would show that in iodoform poisoning free iodine was present in the other secretions and excretions.

Watson Cheyne[2] has described a fatal case of iodoform poisoning. The patient was a child who had two drachms of a 10 per cent. solution of iodoform injected into an iliac abscess. This was followed by collapse, frequent vomiting of blood, carboluria, restlessness, and delirium, inequality of the pupils, and a temperature of 104·6° F.

It is supposed by some that iodoform owes any efficacy it may possess to the liberation of iodine, so that it seems natural to ask why a solution of iodine is not used in the first place. It is claimed, however, that not only does the ethereal and alcoholic

[1] Jaksch, "Clinical Diagnosis," translated by Cagney, p. 343.
[2] *Brit. Med. Journ.*, London, 31st December 1892, p. 1421.

solution of iodoform contain free iodine, but that it also contains a reserve of iodoform capable of conversion into a fresh supply of iodine.[1] A similar value is claimed for the iodoform powder, but it is very doubtful whether its store of iodine is ever really liberated. For instance, I have been unable to confirm the statement that when iodoform is mixed with pus iodine is set free. A mixture of fœtid pus and iodoform was kept at 37° C. for twenty-four hours. At the end of that time the starch reaction gave no result.

Nor have I been able to learn that any iodine was liberated from iodoform dusted upon the skin beneath antiseptic dressings. On many occasions when removing a dressing on the eighth day starch solution has been poured over the skin yet covered with the remains of the iodoform, and without any result.

Clearly iodoform is a drug with peculiar characters, about which much remains to be learnt. Although its disinfecting properties are so feeble, its antiseptic are not to be despised.

In addition to the powder and emulsion of iodoform, we use iodoform gauze, which ought to contain not less than 20 per cent. of iodoform powder. It is

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[1] Von Nussbaum, "Leitfaden zur antiseptischen Wundbehandlung," 5th edition, 1887, p. 84.

made by rubbing the powder into gauze or muslin which has been dehydrated and sterilised. If nothing but iodoform is used, the gauze is apt to part with its iodoform, and, therefore, some surgeons add glycerine. This fixes the iodoform, and renders the gauze soft and supple.

The following is the prescription of the late von Billroth,[1] who was an enthusiastic advocate of iodoform:—Iodoform, 50 grammes; glycerine, 50 grammes; alcohol (95 per cent.) 400 grammes. Ten metres of gauze is uniformly impregnated with iodoform by pulverising the crystals in a mortar with the glycerine, and then adding the alcohol.

Iodoform emulsion for injection into sinuses or abscess cavities was made by Sir Joseph Lister by adding one part of iodoform to ten parts of glycerine. This is improved, I think, by the addition of one part of ether and two of alcohol. But, as might be expected, such a popular remedy as iodoform is applied in a variety of ways.[2] Generally speaking, all the mixtures should be fresh. I have given up

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[1] "Introduction to the Antiseptic Treatment of Wounds according to the Method in Use in Professor Billroth's Clinic," by V. von Hacker, translated by Kilkelly, London, 1891, p. 42. This small work is full of useful information.

[2] These are given in the "Extra Pharmacopœia," Martindale and Westcott, 7th edition, p. 239, *et seq.*

using a made-up mixture of iodoform collodion. It seems to decompose and develop pungent and acrid vapours. It is, as I have just said, much easier and better to apply collodion to the wound, and dust it with iodoform whilst it is drying.

Thus, although the disinfecting properties of iodoform are doubtful, yet its antiseptic render it a valuable adjunct. Therefore, as no bacteria will grow in the presence of dry iodoform, I use it for dusting upon the skin all around, but not within the wound. It seems reasonable to suppose that, if the skin had escaped disinfection, the growth of bacteria from its sweat glands, sebaceous glands, or hair-follicles would be arrested by the iodoform, and not grow as far as the wound. Next, the layer of iodoform seems to me to have a great value in preventing bacteria passing from the exterior of the dressing along the skin into the wound. Moreover, I have occasionally seen the wound protected by the layer of iodoform, although, owing to the struggles of the patient, it had been exposed to the air. The valuable soothing and anodyne properties of iodoform, and its power of preventing dermatitis, need not be referred to again.

PART IV.

CHAPTER XV.

SURGICAL TECHNICS.

We may now begin to apply the foregoing to surgical practice. Our task is the exclusion of bacteria from wounds, and we have seen the means at our disposal for this purpose. It is not enough to pretend to keep out the harmful bacteria from wounds whilst allowing the so-called harmless to enter. To begin with, it is not known which are harmless and which are harmful. Next, a method which is so defective as to admit one kind cannot keep out the other. The presence of any kind of bacterium in a wound proves that the *method* of treatment has failed.

We have now to apply our knowledge of disinfectants and antiseptics to (*a*) the preparation of the surgeon and his helpers; (*b*) the preparation of the patient; (*c*) the preparation of the instruments and materials used at the operation; (*d*) to the operation; (*e*) to the treatment of the wound.

Assistants.

The aim of aseptic surgery is sterility. We endeavour to reach this standard of perfection by the most simple and direct means. A moment's thought shows that as few as possible ought to take part in an operation. Each pair of hands is a danger. The chances of error from ignorance or inadvertence multiply in proportion to the number engaged. Our aim, therefore, is to employ as few as possible. The surgeon does all he can for himself—one assistant suffices for almost every operation; but an amputation of the thigh requires some one to hold the leg, or an amputation of the breast some one to hold the arm. A single nurse is enough for most operations, and her duties are made as simple as possible. The fewer hands touch the sponges or dressings the less the chances of infection. Therefore the nurse's duties are, if possible, confined to handing sponges in a basin of lotion, the iodoform bottle in lotion, the dressing, and so forth.

Instruments.

As regards instruments, we endeavour to use few, and of the simplest kind. This diminishes expense, because

instruments which are sterilised by heat soon deteriorate; also a number of instruments are apt to be confusing to the surgeon, since he alone handles them. Quantities of instruments cannot make up for want of skill. After the instruments have been boiled for fifteen minutes, they are placed in a tray of carbolic lotion (1 in 40 to 1 in 60). The surgeon himself takes the required instrument from the tray, uses it, and returns it to the lotion. In its passage to and fro it touches nothing. I myself never lay instruments or sponges upon towels or upon the patient's body; such repositories may or may not be aseptic, and the instruments are apt to fall upon the floor—rather a misfortune when so few are at hand. We always endeavour to finish an operation with the instruments with which we began. There is no objection to the use of an instrument fresh from the steriliser, provided it has been boiled long enough. I have, however, learned to distrust these emergency instruments. It betokens want of forethought to discover in the midst of an operation that an instrument is wanting, and a want of resource not to be able to make another take its place. The assistant at an operation has nothing to do with the instruments beyond occasionally holding forceps or retracting the edges of the wound. As we have not yet learned how to disinfect the hands with absolute precision, his

fingers should be put into the wound as little as possible, and then only after a thorough rinsing in lotion. No assistant is told off to pass instruments, ligatures, or sutures to the surgeon who is operating. This would entail an extra pair of hands, and be an additional source of error. Sometimes in difficult operations, where swiftness is essential, a trustworthy assistant is told off to thread needles and hand ligatures. He ought to be familiar with each step of the operation, so as to be ready to anticipate the needs of the operator.

It has already been said that air, water, skin, instruments, ligatures, sponges, and other appliances are the usual sources of wound infection. Part of the practice of aseptic surgery consists in the use of the agents at our command, so as to prevent bacteria being introduced from any of those sources. But many other factors, as we shall see, combine to achieve the perfection of aseptic surgery.

We have seen that for purposes of disinfection we possess two agents of unequal value, namely, heat, which is reliable, and chemicals, which are unreliable and difficult to use. But for antisepsis, or, in other words, for keeping disinfected things aseptic, chemicals are quite efficient when skilfully applied. Dilute chemicals may be confidently relied upon to prevent

aseptic instruments, sponges, or drcssings becoming infected from the atmosphere, and, I believc, from the skin. They are also sufficient to prevent infection by water and a few such sources. Our course, therefore, is quite clear; heat is used to disinfect, and chemicals to maintain asepsis. Some things, however, cannot be heated, and here one of our great difficulties arises, because, under such circumstances, we have to trust in chemicals.

Although I am in the habit of using certain chemicals, yet others may bc as good or better. But, as I have already said, it is safer to use chemicals we thoroughly understand rather than those which are recommended upon theoretical grounds.

That which has been sterilised should he handled with care. If, by inadvertence or carelessness, anything becomes infected, ordinary solutions of chemicals could not be trusted to disinfect. Thus a sponge which has been soiled, or an instrument which has been dropped upon the floor, has to be discarded. Very strong chemicals might disinfcct them, but to dip them for a minute into dilute solutions is mere fetish.

Costume for Operations.

The books upon aseptic surgery with which we have of late been flooded contain elaborate descriptions of

operating costumes. After what has been said, no one would touch a wound with any unsterilised article, let alone with the garments. These, therefore, should be arranged so as to avoid any danger of contact. The surgeon and his assistant remove their coats, turn up their shirt sleeves, and put on aprons to protect themselves from jets of blood or the splashing of lotions. If aprons be not at hand, towels serve this purpose very well. The apron, it is hardly necessary to say, not having been sterilised, must never be touched with the disinfected hands, or be allowed to touch the wound. The sisters and nurses are to be dressed upon similar lines. Their sleeves and cuffs are sometimes too long, and are apt to touch the towels, or sponges, or dressings. In other respects, our standard of personal cleanliness is so high in this country that directions which are sometimes given may be omitted.

Disinfection of the Hands.

The disinfection of the hands ought to be first in our procedures. It is inconsistent to disinfect instruments, towels, sponges, and so forth, and then handle them with infected hands. The hands pass through three stages. First, they are prepared for disinfection; second, they are disinfected; and third, the disinfectants

are washed away with dilute chemicals, which act as antiseptics to keep them sterile. To prepare the hands for disinfection, it is hardly necessary to say that rings should be removed. Reverdin's[1] remarks upon jewellery are much to the point. He very properly says the hands should be naked. Even the sacred engagement ring is tabooed. This last sacrifice seems sometimes too much for vanity and superstition. As I have already said, the finger-nails should be trimmed as short as possible with knife or scissors. Afterwards the hands and forearms should be scrubbed with soap and hot water (temperature 105° F.) for three minutes. The object of this soaping and scrubbing is not only to remove all visible dirt, but also to extract as much as possible of the grease from the skin, so that the disinfectants can penetrate. The ordinary soaps are suitable for this purpose, but potash soap is, perhaps, the best. Potash soap, or soft soap, as we generally call it, checks the development of anthrax spores, and presumably of other bacteria. Koch[2] found that a solution of one part in five thousand retarded their development, and that one part in one thousand completely prevented it.

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[1] *Loc. cit.*, p. 87.

[2] *Loc. cit.*, *New Sydenham Soc.*, 1886, p. 514. Every one ought to master this important essay.

The next step is to disinfect the prepared hands. For this I am now using a one in five hundred solution of biniodide of mercury in 75 per cent. rectified spirit, to which a little water and iodide of potassium or of sodium are added to dissolve the biniodide. Ordinary methylated spirit is almost as good as rectified, but not so pleasant to use. A little water ought to be added to these spirituous solutions.

Mixtures of pure chemicals with absolute alcohol are inert. Koch found anthrax spores alive after they had been exposed for seventy days to a 5 per cent. solution of carbolic acid in alcohol. But to obtain such results as these the acid and the alcohol must both be pure. When water is present, even in small quantities, the chemical can act in its usual way.

The hands and forearms are soaked for two minutes in spirit and biniodide. A longer sojourn may be harmful, and is not, I think, required. Finally, the spirit and biniodide are washed off with the biniodide of mercury lotion, which is to be used throughout the operation. The strength of this varies according to the circumstances. For a radical cure of hernia or of hydrocele I usually employ one in two thousand, because the region is one which is particularly difficult to keep aseptic. For an ovariotomy, one in four thousand is used for the sponges, which are well wrung out.

Irrigation.

Should irrigation be called for, sterilised hot water is put into the abdomen. Nevertheless, when septic matter has escaped into the abdomen I have washed it out with a one in four thousand solution of biniodide without any ill result. It seems safe to use the same solution or stronger for localised septic peritonitis or pleuritis.

During the operation the hands are frequently rinsed in a fresh bowl of the biniodide lotion. This cleanses them of blood, and keeps them aseptic. When once the hands have been disinfected, they do not touch anything which is not known to be sterile. Others, therefore, are asked to move the patient into position, pull aside blankets, or move tables. Should the operator or any of his assistants take part in such proceedings, they disinfect their hands before handling any of the sterilised articles, and before interfering with the field of operation. The proper observance of these precepts requires the keenest attention. Proper habits are soon acquired by those who grasp the principles of aseptic surgery.

It is, as a rule, hazardous to perform operations with hands which have been cut or grazed. But if these injuries be slight and uninflamed, and not suppurating,

it is, I believe, safe to cover them with collodion after the hands have been disinfected in the spirit and biniodide. It would be most reprehensible to operate with a suppurating sore upon the hands. It is quite improbable that such a septic sore could be disinfected or occluded.

The spirit and biniodide used in the above process seems to be an efficient disinfectant. Not long ago we placed scraps of skin which had been disinfected with it from the hands of the surgeon, house surgeon, sister, nurse, and patient into culture tubes of sterilised broth. Every one of them remained sterile. The skin was taken at the end of an operation for the radical cure of hernia. Such good results are now quite frequent. Upon another occasion the skin of the assistant, of the sister, and of the nurse were all septic. However, the skin of the hands was sterile in twelve cases out of twenty-two—a much better result than we used to obtain. It is clear that a better method might be found, but much depends upon the care with which our present one is applied.

Koch's experiments showed that solutions of sublimate and carbolic acid in absolute alcohol had no injurious effect upon anthrax spores. But it is to be noted that absolute alcohol has to be used to obtain this result. Spirit is used in our solution because it penetrates the

skin better than water; but only 75 per cent. rectified spirit is used,[1] not absolute alcohol, and a proportion of water is added. Ordinary watery solutions of chemicals run off the skin as soon as they are put on, and often the surface is hardly wetted by them. Such applications must be useless.

Nail Brushes.

The nail brushes which are used for the hands and skin ought to be sterilised in the steam steriliser, and kept in fresh 5 per cent. carbolic lotion or in 1 in 1000 biniodide of mercury lotion. The steaming ought to be repeated without fail whenever the brushes are used to remove pus or virulent septic fluids of like kind.

Glass Jars.

Glass jars are the best for keeping brushes, silk, sponges, and so forth. It is rather hard to obtain the right kind of jars. These ought to be made with a glass lid to fit over and surround the outside of the mouth or neck of the jar. When the mouth is closed with the ordinary glass stopper a chink is left betwixt the stopper and neck of the bottle. Dust collects

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[1] Methylated spirit may be used, but is not quite so agreeable as the rectified.

in this chink and falls into the bottle every time it is opened. Should a jar with a proper glass lid not be at hand, the stopper and neck of the ordinary ones should be kept covered with a cap of stout paper or waterproof jaconet. Also the chink ought to be wiped round with a bit of gauze or alembroth wool soaked in 1 in 1000 biniodide solution, or 1 in 20 carbolic acid lotion, before the stopper is taken out. The jars ought to be quite air-tight. Carbolic acid soon evaporates, so that after a while the brushes, sponges, or ligatures may be lying in a dangerous and septic fluid. In any case solutions of carbolic acid ought to be renewed at frequent intervals; once a week is the rule at St. Bartholomew's.

CHAPTER XVI.

DISINFECTION OF THE SKIN.

The Preparation of the Patient.

The preparation of the patient may be described next, because the disinfection of the skin is an important part of the process. In hospitals the patient is got ready in a routine manner, but it is not always necessary or desirable to treat every case alike. The methods which are necessary to disinfect the harsh, thick, neglected skin of some hospital patients would be harmful to the delicate skin of a child or lady. Moreover, skin which is clean and cared for is easier to disinfect than that which is dirty and neglected. Other circumstances, too, may necessitate slight alterations in matters of detail. These will be mentioned as I proceed.

I propose to describe first the preparation of a patient who has no septic sore or sinus from which the wound could be infected. The presence of a septic sinus or sore near the site of operation is a dangerous complication, and calls for special precautions.

Operations are not done upon those who have unsound kidneys or other organs, except in case of necessity. But when such patients have to be operated upon, aseptic surgery robs the operation of many of its perils.

Supposing, therefore, that the great organs have been examined and found to be healthy, and that there is no septic process going on, we proceed as follows :—

The evening before the operation a purge is given This unloads the bowels, so that the patient is not disturbed and does not feel uncomfortable for a few days after the operation.

The skin is prepared after the patient has had a hot bath, with plenty of soaping and scrubbing. It passes through the same stages as the skin of the hands. First, it is prepared for disinfection ; second, it is disinfected ; and third, it is protected and kept aseptic until the operation.

In most cases the first step is to thoroughly shave the skin. When hairs are present they impede the operation and render the dressing insecure ; moreover, they harbour bacteria, especially in the mouths of their follicles. The whole area involved in the operation ought to be shaved ; for trephining and similar procedures the whole scalp, or the whole thigh, when amputation is to be done through the femur. At

hospitals and nursing homes some one is usually employed to do the shaving. Sometimes it has to be done by the surgeon or his assistant just before the operation. This is always troublesome, because it is so difficult to get rid of the loose hairs. They ought to be taken away with wet wool, and at once thrown upon the fire.

After the skin has been shaved it is thoroughly cleansed of dirt and surface epithelium by energetic scrubbing and soaping. The epithelium always harbours bacteria, but most are present when it is thick and sodden. Such thickened epithelium is best removed with a sharp spoon, either before or at the operation. The extraction of the fat and sebaceous matter is of the highest importance. As I have already said, sebaceous matter is a mass of bacteria and degenerated epithelial cells. It has, therefore, to be extracted from the ducts of the sebaceous glands. Moreover, it is useless to expect disinfectants to penetrate skin which is full of fat. Whatever chemical was put upon the surface, bacteria would continue to live in the depths of the follicles and sweat glands. Thus the removal of the fat is imperative. For this purpose much reliance may be placed upon energetic soaping and scrubbing. But after this we rub and bathe the skin with ether or spirits of turpentine. Ether is clean and rapid, and

leaves a surfaee into whieh the disinfectant sinks easily. Turpentine is eheap, has slight disinfeeting properties, and helps to remove dirt from the surface. It has been aseertained[1] that turpentine had little effeet upon *bacillus prodigiosus* or *staphylococcus albus;* that *staphylococcus pyogenes aureus* did not grow well after it had been three hours in turpentine, and was killed in five hours.

Koeh's[2] experiments showed that the vapour of oil of turpentine failed to affeet earth spores in sixty days, and ten days' exposure of anthrax spores to water containing a few drops of oil of turpentine, with frequent shaking, gave a similar negative result. The pure oil killed anthrax spores in five days, but failed to do so in one day. The development of anthrax spores is prevented by 1 in 75,000.

As a rule, I find that house surgeons prefer to use ether. The methylated kind is quite good enough for the purpose. The sisters and nurses praise turpentine for eleansing the feet or hands or knees of labouring people. Ether or turpentine may be rubbed in with a swab of absorbent eotton wool.

The baeteria whieh inhabit the duets of the sweat

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[1] Christmas Dirckinck-Holmfeld, "Das Turpentinöl als Antisepticum," *Fortschr. d. Med.*, Berlin, 1887, p. 617.

[2] "On Disinfection," p. 510.

glands and mouths of the hair follicles are either removed by these measures, or the disinfectants are enabled to reach their hiding places. These measures likewise get rid of or lay bare to disinfection the bacteria which inhabit the ducts of the sweat glands and the mouths of the hair follicles.

After the skin has been shaved, cleansed, and its sebaceous matter extracted, it is disinfected with chemicals. After what has been said it is obvious that dilute solutions would have no effect. We therefore soak the prepared skin for two minutes with the same solution of spirit and biniodide of mercury as that which was used to disinfect the hands. This consists of 1 part of biniodide dissolved with the help of iodide of potassium and water in 500 parts of rectified spirit. Before use a tenth part of hot water is added to render the action of the drug more certain. This spirituous solution spreads evenly upon the skin, and seems usually to penetrate its depths. In the last series of cases treated in this way eleven out of twenty-one were aseptic. Some of this skin was from regions which are the hardest to deal with. As we gain experience and learn how difficult it is, and what strenuous exertions it requires to disinfect the skin our results improve. It is clear, however, that we are far from having learnt the best way of disinfecting

the skin. But the nature of the problem is such that more will always depend upon the care with which the skin is prepared for disinfection than upon the kind of disinfectant which is applied. After the skin has been disinfected it has to be kept aseptic until the operation. For this purpose we place next to the skin a layer of 5 per cent. carbolic gauze which has been soaked in biniodide of mercury lotion for at least twelve hours. This lotion contains 1 part of biniodide in 2000 parts of water. It is advantageous to use glycerine instead of water, but as solutions of disinfectants in pure glycerine are inert, the whole of the water ought not to be replaced with glycerine. Dr. Black Jones and Mr. Furnivall grew bacteria from threads which had soaked for ten minutes in fresh glycerine and carbolic acid, one part in twenty. Glycerine in biniodide, 1 in 2000, and glycerine in perchloride, 1 in 1000, did not disinfect in one minute. The addition of glycerine keeps the gauze continually moist, and also helps the disinfectant to soak into the skin. This layer of wet gauze is covered with a layer of alembroth wool, and an outside dressing bandaged over the whole. The outside dressing should fit accurately, and may be used again after the operation. It consists of eight layers of 5 per cent. carbolic gauze covered with a layer of waterproof jaconet. Its construction and uses will be described

when I come to the final dressing of the wound. When there is a septic ulcer or sinus in the skin which has to be prepared for operation the process of disinfection is much more difficult and uncertain. Not only should an attempt be made to disinfect such as these before the operation, but after the patient is anæsthetised they ought to be thoroughly scraped with a sharp spoon, soaked with pure carbolic acid, or touched with the actual cautery, irrigated with 1 in 1000 biniodide of mercury lotion, and shut off as far as possible from the field of operation by packing them with carbolic gauze. Sometimes a layer of gauze soaked in iodoform collodion seals the infected region, and affords a fair protection. The only case I have lost from septicæmia was infected from a cancerous ulcer which had not been properly disinfected. I was not then aware of the impotence of our chemicals.[1]

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[1] Hunterian Lectures on "Traumatic Infection," Edin. and Lond. 1895, p. 50, *et seq.*

CHAPTER XVII.

PREPARATION OF INSTRUMENTS.

THE preparation of the instruments has been mentioned more than once. The following suffice for almost every operation, namely, a knife, a pair of scissors, a pair of dissecting forceps, six to twelve pairs of pressure forceps, a straight needle, and a curved needle. For special operations amputating knives, saws, bone forceps, blunt pointed needles on handles, and such like may be wanted in addition, but the foregoing are the stock ones. Every one of the instruments are put into boiling water for fifteen minutes, they are taken from the water without contamination, and arranged in a basin or tray filled with 2 or 2½ per cent. carbolic lotion.

If the operation is at a distance the instruments are boiled at home in a saucepan or small fish kettle, and wrapped whilst hot in an ordinary outside dressing. This protects them from infection, and after the operation may be used for dressing the wound.

Frequent boiling certainly destroys the instruments. It does not seem to blunt the cutting instruments if

they are protected from contact. Therefore the knife ought to be put in a rack or rolled in a thin layer of wool or muslin. Needles are best tied together with a bit of silk before being put into the boiling water.

The same instruments may be used for several operations, provided they have touched nothing septic. They merely require to be placed in fresh lotion. Of course the knife must be replaced if it has been blunted.

After the operation the instruments ought at once to be thoroughly cleansed of blood by an energetic scrubbing with soap and hot water. This makes their subsequent disinfection much more easy and safe.

It is unnecessary to say that the old fashioned instruments with wooden or ivory handles are useless now. But instrument makers are gradually learning to make instruments with metal handles. For needles and retractors the bent wire handle, like that of a penny button hook, is simple and very easy to hold.

All the other instruments which may be required for an operation are sterilised by heat, and kept aseptic with dilute chemicals. Should heat be unobtainable I often disinfect the instruments for a dressing by dipping them in pure carbolic acid for a minute.

The instruments are used with proper precautions. As I have said, the surgeon himself picks the instrument he requires from the tray of lotion, uses it, and

puts it back in the tray. During its transit from the lotion to the wound it touches nothing, or, at all events, nothing but things which have been sterilised and soaked in lotion. It is unnecessary to point out how irrational it is to disinfect instruments and then allow them to touch that which is infected.

Preparation of Silk.

Twisted silk is used for tying vessels, sewing together divided muscles or aponeuroses, or for securing pedicles. The smallest size is 00, and is suitable for the smallest vessels; but the larger sizes, 0, 1, 2, 3, 4, 5, and 6 are used according to circumstances. The quantity required for the operation is rolled upon a glass reel or glass microscopic slide, and is prepared by boiling for fifteen minutes to half an hour in water. The shortest boiling suffices for the thinnest kind, provided too much is not rolled upon the glass reel. After twice boiling the silk becomes brittle and unreliable, especially the thinnest kinds. After having been disinfected, the silk is put in a bowl of 2 or 2½ per cent. carbolic lotion, from which it is taken by the surgeon. It should be handled as little as possible, and touch nothing unsterilised in its passage from the lotion to the wound; indeed, it is best if it touches nothing whatever. Silk which has to

be transported is placed in a jar of 5 per cent. carbolic lotion. This strength allows a little for evaporation, but is rather too strong for the surgeon's hands. The silk, therefore, is taken from it at the operation and put in 2 or $2\frac{1}{2}$ per cent. lotion.

Preparation of Silkworm Gut.

Silkworm gut, or fishing gut, as it is also called, is used for skin sutures, and not infrequently for buried sutures too. It is quite unirritating, and, owing to its physical properties, has no capillarity. Thus when it is placed in the skin no fluids can pass along it either into or out of the wound. It is prepared by boiling and immersion in lotion the same as the twisted silk, and bears the treatment exceedingly well. One or two boilings seem to have no effect upon it, and soaking in lotion only makes it tougher and stronger. The thickness of the fishing gut ought to be proportionate to the strain it has to bear. For a laparotomy wound thick strains should be chosen, but thin ones do for ordinary skin wounds.

This mode of preparing silk and fishing gut is quite reliable. Nine specimens were tested during this year and last by dropping bits of them into broth. In every instance the result was aseptic.

Preparation of Catgut.

For some wounds, such as circumcision, or wounds about the face, ordinary raw catgut is a valuable material, as it does not require to be taken out. Moreover, some surgeons use it for the ligature of vessels. Catgut prepared after Esmarch's[1] directions is, I have found, quite sterile. His method is as follows:—The ordinary commercial catgut, Nos. 1 to 3, is vigorously cleaned with a brush in soft soap and water, and after washing in pure water, is wound on glass spools and laid in bichloride of mercury solution, 1 to 1000, for twelve hours; then in an alcoholic 1 to 200 solution of bichloride for twelve hours, and it is then preserved dry in tightly closed glass vessels. Just before it is used it is laid in a vessel filled with an alcoholic 1 to 2000 solution of bichloride of mercury.

In this process the scrubbing with soap and water is very important. Reverdin[2] has pointed out that as a last stage in its manufacture the catgut is oiled. If this grease were left it is unlikely that the disinfectants would penetrate. Soaking in ether may be used to help its removal, and the perchloride which Esmarch uses may be advantageously replaced with the same strength of biniodide of mercury.

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[1] "The Surgeon's Handbook," translated by Curtis, 1888, p. 15.

[2] "Antisepsie et Asepsie chirurgicales," p. 121 *et seq.*

Reverdin[1] sterilises raw catgut which has not been oiled by putting it in the dry-heat oven for four hours at 140° C.

Some wounds require a drainage tube of glass or india rubber. These are disinfected by boiling in exactly the same way as the instruments. They are usually kept with the ligatures and sutures. I always drain wounds which pass through septic sores or sinuses. It is doubtful whether these wounds can be made aseptic by any of our present means. Harm ensues if septic fluids are allowed to collect within them. I also drain wounds in parts where pressure cannot be applied, and in which blood easily accumulates. Thus a drain is always put into scrotal wounds after radical cure of hydrocele or varicocele, or after castration. It is also wise to drain wounds in which there is oozing of blood. After amputation through the condyles of the femur, or after Syme's amputation, the cancellous tissue of the bones is very apt to ooze. The blood collects within the flaps, and not only causes pain, but also predisposes to suppuration should asepsis not have been achieved. As a rule the drain is taken out at the end of forty-eight hours. After amputation such an early dressing is exceedingly painful, and therefore the tube is left

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[1] *Loc. cit.*, p. 128.

until the eighth or tenth day. By that time the wound is almost healed, so that all the sutures may be removed as well as the tube. A little iodoform emulsion is squirted into the opening left by the tube, and it speedily closes.

Preparation of Towels.

Towels are used to spread upon the tables which hold the bowls for instruments, ligatures, and sponges; and also for surrounding the field of operation, and for barring off any septic region like the scalp. Mere soaking in strong solutions of chemicals cannot be relied upon to sterilise these towels. Out of four towels which had been soaked for two hours in 1 in 20 carbolic lotion one was aseptic; the other three infected broth with *staphylococcus pyogenes albus,* with cocci singly and in pairs, and in strings of seven or less, and with a white mould. Another towel, which had been kept in carbolic lotion 1 in 25 for twenty hours, grew a bacillus with a strong sebaceous odour. Towels are seldom soaked in perchloride of mercury, because it discolours them. A towel which had been in 1 in 2000 sublimate for some time contained *bacillus subtilis,* but another which was immersed for three hours was sterile.

These difficulties are easily overcome by boiling or

steaming the towels for half an hour. But it is important to open out the towels before they are boiled or steamed. We omitted this precaution when we first began this plan. Although the towel had been steamed for half an hour, and soaked in 1 to 20 carbolic lotion for more than half an hour, it grew staphylococci, cocci in chains of six, and a spore-bearing bacillus such as I have often seen in cultures inoculated with skin scraping. After what has been said, it may be supposed that these escaped by being protected from the steam by the folds of the towel. When the towels are taken from the steriliser, they are put into carbolic lotion, 1 in 40. The surgeon himself or his assistant takes them out of this, wrings out the excess of lotion, and uses them to surround the field of operation.[1] The last nine towels which were tested after having been prepared in this way were all sterile.

Preparation of Sponges.

Of all the materials which I have had to use, or seen used, for clearing wounds of blood, none seems so satisfactory as a good sponge. The main objection to sponges is that they are difficult to cleanse

[1] C. B. Lockwood, "Report upon Aseptic and Septic Surgical Cases, with special reference to the Disinfection of Skin, Sponges, and Towels," *Brit. Med. Journ.*, 27th January 1894.

and disinfect, but the following method gives reliable results if properly carried out by a conscientious person. If the sponges be new, they are thoroughly shaken and beaten to get rid of the sand which is put into them to make them heavier. To remove the bits of coral and of shell they are soaked for twenty-four hours in a solution of hydrochloric acid and water. This is made by adding a drachm of strong acid to a pint of water. Next they are washed and squeezed out in warm water, temperature 100° F., which has been boiled and left to cool in a covered vessel to ensure its sterility; from this they are transferred for half an hour to a warm solution of ordinary washing soda (ʒj to Oj water) for the removal of any fat or albumin. Sponges full of blood, fat, and albumin may require several repetitions of this part of the process. The soda solution is removed by again rinsing in warm sterilised water, temperature 100° F., and the sponges immersed in cold solution of sulphurous acid (1 in 5) for twelve hours for a final bleaching and sterilisation. This solution is made by simply adding liquid sulphurous acid to water. During this stage a plate is placed over the sponges to sink them in the solution, otherwise they are apt to become discoloured. Lastly, the sulphurous acid is washed out with sterilised water, and they are squeezed as dry as possible, and placed in carbolic lotion

(1 in 20) ready for the operation. Of course other lotions may be used for the purpose. During the operation the sponges are handed to the surgeon or his assistant in a bowl of lotion. The advantages of biniodide of mercury lotion for this purpose have been pointed out. Blood is so easily squeezed from the sponges when it is used, that it is seldom necessary for anyone but the surgeon or his assistant to touch them again. The lotion in which the sponges are handed not only ensures their sterility, but also helps to keep the hands of the surgeon and of his assistant aseptic. A sponge should be taken from the lotion, applied to the wound, and returned to the lotion. It is most dangerous and objectionable to lay sponges upon the body of the patient or upon the table, or even upon the sterilised towels. They are apt to fall upon the floor or be brought in contact with things which have not been disinfected.

To save the troublesome preparation of sponges, we use as few as possible. Six are enough for any operation, but for an abdominal section a flat sponge may be required as well. After sponges have been used with sublimate solutions, the preparation with sulphurous acid is apt to make them rather black and dingy. This is of no real consequence, and can be avoided by using strong chlorine water in place of the sulphurous acid

solution. The chlorine is apt to make the sponges pink and sometimes rather friable.

The chlorine solution is made by putting twenty grains of powdered chlorate of potash into a stoppered bottle, and adding to it two drachms of strong hydrochloric acid. The stopper is left out for ten minutes until all the air is expelled from the bottle. Then two pints of water are gradually added, and the bottle well shaken. This solution has various names. It is called Mistura Chlori, Liquor Chlori, and Gargarisma Chlori. I am indebted to Mr. Parsons for these details.

Sulphurous acid is a disinfectant of some value. Sternberg found that micrococci were destroyed in two hours by 1 : 2000 by weight of SO_2 added to water. Kitasato found that solutions of sulphurous acid in the proportion of 0·28 per cent. killed the typhoid bacillus, and 0·148 per cent. the cholera spirillum. De la Croix found that one gramme of SO_2 added to two thousand of bouillon prevents the development of putrefactive bacteria, and after a time destroys the vitality of these bacteria. Sternberg found that pus cocci failed to grow in a culture solution containing 1 part of SO_2 in 5000 of water.[1]

Chlorine is an active germicide in the presence of moisture. Fischer and Proskauer found that moist

[1] The above is quoted from Sternberg's "Bacteriology," p. 172.

anthrax spores exposed to a moist atmosphere containing 4 per cent. of chlorine, were killed in an hour. A moist atmosphere containing 1 part in 2500, killed anthrax bacilli and *micrococcus tetragonus* in twenty-four hours, and the streptococcus of erysipelas in three hours.[1] I quote these observations because they show the potency of chlorine, and because of their bearing upon the disinfection of rooms. Koch found that anthrax spores did not grow after twenty-four hours in chlorine water. According to De la Croix, no bacteria developed in unboiled beef infusion when chlorine was present in the proportion of 1 : 15,000. Miquel also gives chlorine a high antiseptic value.

The methods which I have just described for the disinfection of sponges is reliable. Out of twelve which were tested by cutting off a scrap and putting it into broth, eleven were sterile. The one which was septic grew *staphylococcus pyogenes albus.* The nurse who handed it was inexperienced. In a second series of thirteen one was septic. It contained a bacillus with peculiar characters, and different from any I have seen before.

Preparation of Bowls and Irrigators.

The bowls used for instruments and sponges are disinfected by heat, otherwise they are a great danger.

[1] Sternberg, *op. cit.*, p. 169.

The usual wiping with carbolic lotion is quite untrustworthy. Dried pus or septic fluids would not be disinfected by such a proceeding. Therefore the bowls should be steamed or boiled for at least fifteen minutes. If this cannot be done, Forgue recommends that in country practice they be flamed with a little alcohol.[1] Very few bowls are required. The surgeon has one for his instruments, one for needles and ligatures, and one for the lotion in which he rinses his hands.

The nurse requires one bowl in which the sponges are given to the assistant. These sponges are handed in the lotion, from which the assistant squeezes them dry before sponging the wound. As a rule, the assistant himself cleanses the soiled sponges by squeezing them out in lotion. The nurse has merely to hand a fresh bowl of lotion. This can be kept ready mixed in a large jug or in another bowl. The apparatus of the anæsthetist must not be washed in the sterilised bowls used for the operation. Also the nurse must on no account touch his sponges or lint. It is better that he should defer his cleansings until the wound is safely covered with the dressings. Accomplished anæsthetists are on the alert to guard against infection from anything they have used.

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[1] "On Asepsis in Current Surgical Practice in Urgent Cases and Country Practice," *The Medical Week*, vol. i., No. 45, p. 536.

It is needless to say that if an irrigator is used it ought to have been sterilised. For most operations, particularly those done upon the abdomen, I find an ordinary earthenware jug the simplest and best irrigator.

CHAPTER XVIII.

THE OPERATION.

When these preparations have been made the patient is anæsthetised, taken to the operation room, and put upon a convenient table. This table should be wide and long enough to hold the patient, and should stand by itself in the centre of the room. The space around it should not be encumbered with spectators. Ample room must be kept for the surgeon's table of instruments, and for the nurse and her appliances. She ought to be allowed to pass whatever the surgeon or his assistant needs without any danger of touching the onlookers.

Anæsthetists who know the principles of aseptic surgery are careful to keep their lint or apparatus out of the field of operation. In operations about the head and neck this is not at all easy to manage. But, as a rule, the mouth and nose can be put in such a position as to avoid danger of infection from them. Moreover, a barrier of disinfected towels can usually be raised betwixt the wound and the anæsthetist. I have tried

various kinds of barriers and screens. None are of use without the help of a trained and zealous anæsthetist who stands out of the way behind the patient's head.

For most operations the surgeon stands upon the right-hand side of the table, the assistant on the left, and the nurse behind the assistant. The surgeon's instruments are put upon a table, so that he can pick them up without stepping from the position taken up at the beginning.

The patient having been anæsthetised, is arranged upon the table in a convenient attitude. This is chosen with care, because it is dangerous to upset the field of operation in the midst of an operation by moving an ill-adjusted patient.

The Field of Operation.

To prepare the field of operation the superfluous garments or blankets are taken away, but all unnecessary exposure is guarded against. The loss of heat is very great when a large area of skin is exposed to the air and wetted with lotions. The patient's body should be clothed in warm flannel garments, and the feet in stockings. When the patient is old or debilitated we wrap as much as possible of the trunk and limbs in layers of cotton wool. Shock can also be lessened by

using hot appliances, by placing the patient upon a hot-water table or hot-water mattress, by stimulants before, during, and after the operation, and by cultivating that speed in operating which modern surgery demands. Therefore the area of operation, and nothing more, is laid bare, disinfected, and surrounded with aseptic towels. These, after the dressing has been taken away, are arranged all round the field of operation, so that it is impossible for the hands of the surgeon or of his assistant, or any of their instruments, ligatures, or sponges, to touch anything which has not been disinfected and wetted with lotion. A thin mackintosh may be placed beneath the towels to keep the patient's clothing and blankets dry.

For laparotomy the abdomen is sometimes covered with a mackintosh apron with a hole in it to surround the incision. The edges of the hole in the apron are fastened to the skin with soap plaster. I do not use an apron of this kind, because it cannot be sterilised.

When a part which is difficult to disinfect is near the field of operation, it should be covered with a shield of carbolic gauze which has been soaked in biniodide lotion. In operations for the radical cure of hernia, of hydrocele, or varicocele, it is especially important to shut off the organs of generation with such a shield.

At times the rectum or other septic orifice has to be excluded by the same device.

An operation founded upon the principles of aseptic surgery is a bacteriological experiment. If our disinfectants and antiseptics were perfect, and surgeons, assistants, and nurses infallible, wound infection would never be known. But even now a death from septic infection causes much searching of the heart, and suppuration is a deep reproach.

General Outline of Operation.

Aseptic surgery has made a vast addition to the number and range of surgical operations. At the same time it has altered our standard of perfection. But to attain this standard much is needed besides the exclusion of bacteria. Precision in diagnosis, knowledge of anatomy and pathology, and swiftness and dexterity in operating are as essential as ever. The details of the operation must be so familiar that attention can still be given to the supervision of those who are assisting. All this would be beyond our faculties when preoccupied with a difficult and anxious operation unless we used the simplest methods and appliances, and unless aseptic surgery had become a habit, done without reflection.

I do not propose to describe the actual performance of the operation; that will depend upon many circumstances. But all incisions should be clean and regular, and adapted for perfect apposition. Moreover, the skin incision ought to be placed so that after the operation it can be covered with the dressing far beyond its limits, and air absolutely excluded. It has made a great difference in the radical cure of hernia to transfer the incision from the scrotum to the groin. Bleeding ought to be stopped at once to prevent infiltration of the tissues with blood; bruising and laceration ought to be avoided, and therefore everything must be done neatly and gently. Neither fingers nor instruments should be put into the wound except for a distinct purpose, and the tissues are not to be strangled with ligatures or sutures.

Swiftness in operating not only helps to diminish shock, but also lessens the danger of infection from the air or other sources. In many abdominal operations speed is essential to success. During the operation and before the wound is sewn up it is irrigated with biniodide of mercury lotion. This washes out any bacteria which may have entered from the air, and cleanses away blood or particles of fat. The biniodide seems to have no evil effect upon the tissues, and leaves them as fresh and clean as if they had been washed with water. The

appearances are very different from those produced by irrigation with sublimate or carbolic lotion.

The wound is closed with scrupulous care. If the skin is brought into perfect apposition it speedily unites, and shuts off the depth of the wound from the atmosphere in case the dressings are imperfect or become disturbed. Moreover, a much less unsightly scar is left. Before the last suture is tightened any remains of blood or lotion is squeezed from the wound, and pressure applied with sponges.

The Dressing.

The dressing which I use nearly always consists of (*a*) dusting with finely powdered iodoform crystals; (*b*) a layer of 5 per cent. carbolic gauze which has been soaked in biniodide lotion; (*c*) a layer of alembroth wool; and (*d*) an outside dressing and bandages.

The object of these dressings is as follows:—The iodoform is dusted upon the skin, especially in its folds and creases, to act as an antiseptic in case of imperfect disinfection. Should bacteria emerge from the sebaceous glands, sweat glands, or hair follicles, they could not multiply or spread in this layer of iodoform. Moreover, the iodoform lessens the danger of blistering, and diminishes any irritation caused by the

other chemicals. The iodoform also protects the wound if the dressing is disturbed by the movements of the patient. I have seen the wound of a radical cure of hernia exposed to the air, but nevertheless heal perfectly because it was protected by its covering of iodoform.

The iodoform is handed to the surgeon in a small glass bottle with a perforated cover. This bottle ought to be disinfected after it has been used for a septic or tuberculous case. It is always handed to the surgeon immersed as far as its perforated cover in antiseptic lotion. Otherwise the surgeon's hands would be infected by it, and require disinfection before he touched the rest of the dressing.

The layer of 5 per cent. carbolic gauze is soaked before its application in biniodide of mercury lotion to remove and disinfect any dust which may have fallen upon it. It is usually soaked for twelve hours. In various trials it has never infected broth. It is probable that a shorter time would suffice. The gauze is wrung out as dry as possible before being put upon the wound. This layer of aseptic gauze protects the skin from the strong alembroth contained in the next layer of dressing, and it also contains a store of carbolic acid for the disinfection of any fluids which now and then escape from the wound. But as this store of carbolic

acid is small and of feeble value, a thick layer of alembroth wool is placed over the layer of carbolic gauze This wool, as I have already said, contains 2 per cent of sal-alembroth. It soaks up any blood or fluid, and at the same time makes them antiseptic. Therefore, if by chance the fluid spread beyond the edge of the dressing, bacteria would still have difficulty in finding their way into the wound. It also diminishes the risk of air infection and equalises the pressure which is applied to the wound. The alembroth wool must be separated from the skin by a wide-spread layer of soaked gauze, otherwise it is apt to cause dermatitis and blistering.

The layer of alembroth wool is covered with an outside dressing. This consists of eight layers of carbolic gauze covered with a layer of waterproof jaconet. The outside dressing is very important, and serves several purposes. Without preventing the diffusion of gas it ought to seal the wound against the entrance of free air, or, in other words, against bacterial invasion. It ought also to prevent fluids of any kind reaching the wound from the outside. This is apt to occur when the radical cure of hernia has been done upon children. Their dressings are very prone to be wetted with urine. Should any fluids escape through the other dressings from the wound the outside dressing

makes them spread amongst the alembroth wool and prevents them reaching the air. To fulfil these duties an outside dressing must be of large size, must fit very accurately, and be carefully adjusted. Of what use can it be to take all kinds of precautions before the operation, and after all leave the wound exposed to the air? A proper fit being so important, I always have outside dressings cut to pattern. Also webbing straps and buckles are sewn to the corners to keep them in position. Lastly, the outside dressing is firmly fastened on with a layer of bandaging. This both keeps it in position and makes pressure upon the wound. Sometimes an elastic bandage is required, or layers of adhesive plaster. Some kinds of outside dressings are very hard to fit and adjust, but the trouble which is taken to obtain a good fit is amply repaid. Not only is the patient more comfortable, but his movements are less likely to let the air in beneath the dressing. A radical cure of hernia is very hard to dress. It is best to make a paper pattern of the outside dressing the day before the operation. The dressings for the radical cure of hydrocele and varicocele, and for amputation of the breast ought all to be cut to pattern.

I also find that it is most advantageous to fasten the outside covering in place with straps and buckles sewn to its corners. This not only adjusts the dressing, but

I have known it keep its place when the bandages have slipped. The dressing which I use for radical cure of hernia is fastened with a strap and buckle round the thigh, and another round the pelvis.

For radical cure of hydrocele, varicocele, and in operations on the scrotum or testes I use a triangular outside dressing. This is adjusted by a strap and buckle round the waist, and by two straps which spring from the apex of the triangle, and are brought from the perineum upwards round the thighs at the gluteal fold. Pressure is obtained by stuffing wool beneath the dressing. No other bandaging is required, and the patient can move about with freedom, and is very comfortable.

A well-adjusted and secure dressing is thoroughly appreciated by the sisters and nurses. It enables them to move the patient without fear of spoiling the result.

The outside dressings for amputation of the breast, amputation of the limbs, and operations upon the head and neck, all require special precautions. However, they present few difficulties to those who understand what has to be accomplished. The dressing which I have described is almost a dry dressing.

By the time it is completed we have erected the following barriers against infection from without:—(1) An outside dressing adjusted with bandages and straps. (2) A layer of carbolic gauze and alembroth wool. (3)

A layer of iodoform. (4) Accurate apposition of the skin by suturing. At the same time pressure is applied to arrest hæmorrhage and prevent inflammatory effusion. But after an aseptic operation in which the bleeding is thoroughly staunched, there is no moisture about the wound, so that no call is made upon the blue alembroth wool. As a rule there is merely a slight dry blood stain upon the gauze which touches the cut.

This kind of dressing gives me good results. At times the carbolic gauze is apt to become rather hard, but it hardly ever blisters the skin. It is quite unusual for a wound to be dressed before it has finished healing. But when the weather is hot and the skin is delicate I sometimes use iodoform gauze instead of carbolic gauze and alembroth.

So long as the dressing fulfils the principles of aseptic surgery its composition is of minor importance. But no kind of dressing can avail if the principles of aseptic surgery are violated at other stages of the operation.

After Treatment.

The after treatment of aseptic wounds gives little trouble. The healing is unaccompanied by constitutional symptoms, but if the operation or injury is extensive the usual complications are to be looked for. At first

there is shock, during which the mind and vital functions are depressed and the temperature lowered. Then in a few hours shock is followed by reaction, during which the pulse is quickened and the temperature moderately raised. These symptoms speedily subside, and do not recur when the wound is aseptic, and with the exception of the wound or injury the patient's health is restored. It is unnecessary, after reaction is over, to put the patient upon low diet, or to interfere with the minor indulgences, such as wine and tobacco; these in moderation do no harm.

The significance of a rise of temperature depends upon the kind of operation as well as upon the way in which it was done.

The course of an aseptic wound is comparable to that of a simple fracture, and in this, as is well known, moderate rises of temperature are not infrequent during reaction.

Elevations of temperature after operations have been attributed to chloroform, chilling by exposure of the surface during the operation, the absorption of carbolic acid, the ferments of coagulating blood, the nervous system, to reaction, and, lastly, to the action of bacteria.[1]

[1] Max Edelberg ("Klinische und experimentelle Untersuchungen über das Wundfieber bei antiseptischen Behandlung," *Deutsche Ztschr. f. Chir.*, Leipzig, 1880, p. 62), gives a synopsis of literature up to 1880, but the asepticity of Professor Wahl's wounds was not tested.

Obviously it is rash to choose any one of these and say that it alone is the cause of fevers after operations. But when the temperature of reaction does not subside, but becomes higher, constituting traumatic fever, wound infection is probable. This traumatic fever may be due to the absorption of bacterial poisons or ptomaines from the wound, or to the passage of bacteria into the circulation by the veins or lymphatics. Von Eiselsberg[1] has obtained *staphylococcus aureus*, *staphylococcus albus*, and *streptococcus pyogenes* from the blood of ordinary cases of traumatic fever following such things as the removal of parotid tumour, Syme's amputation, and resection of tarsus; also in cases of lymphangitis and panaritium ossale. My own work upon the tissues of those who have died after high temperature, but without the usual symptoms of septicæmia or pyæmia has often revealed the unsuspected occurrence of capillary bacterial emboli. In traumatic fever bacteria enter the circulation oftener than is thought.

Aseptic Healing.

Aseptic wounds heal without the usual signs of inflammation. There is neither heat, redness, nor

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[1] "Beiträge zur Lehre von den Mikro-organismen in Blüte fiebender Verletzen, &c.," *Wien. med. Wchnschr.*, 1886, p. 133.

swelling, and function is soon restored. Repair is rapid, and the edges of the incision and the stitch holes preserve the natural colour of the skin. There is a singular absence of moisture, and cicatricial tissue is not developed, so that no subsequent contraction or deformity need be apprehended. If by accident or design the dressings are in contact with a raw surface they are apt to adhere and become incorporated with the reparative material.

Aseptic wounds are also singularly painless. Pain is, however, caused by many things which have nothing to do with the presence or absence of bacteria. Nervous patients imagine pains; nerves may have been injured or included in ligatures; sutures may have been pulled too tight; or the skin may have been left unavoidably stretched. Thus an aseptic wound may be painful at first, although in the end its healing is perfection.

Those kinds of healing which are called healing by immediate adhesion, healing by primary union, or healing by first intention, may be taken as types of aseptic repair. The repair of subcutaneous wounds and injuries is also typically aseptic. Healing by second intention, healing by granulation, and healing by third intention are septic processes, as are also some kinds of healing by scabbing.

Catheters.

The urine has sometimes to be drawn off after operations. If this be not done aseptically a troublesome and dangerous cystitis may ensue. It is quite safe and easy to boil glass, metal, and soft rubber catheters. After disinfection these should be placed in lotion, like the instruments used for any other operation. Before the catheter is passed an attempt should be made to disinfect the meatus urinarius. Although far from perfect, glycerine of carbolic (1 in 40) or glycerine and biniodide (1 in 2000) is the safest lubricant.

An aseptic wound is not dressed until it has healed. The time for the removal of the dressing, therefore, depends upon the nature and extent of the operation. But if a drainage tube has been inserted to let out blood, it is removed in forty-eight hours

Subsequent Dressing of Wounds.

It is a critical time to dress a recent wound. It has to be done with exactly the same precautions as the operation. Everything brought in contact with the wound is sterilised with heat[1] and soaked in antiseptics. Those who perform or assist at the dressing prepare themselves as for an operation. As the wound ought

[1] *See* Footnote, p. 177.

not to be left exposed for a minute longer than is necessary everything is got ready in advance, and the tube removed, and the dressing replaced, in a smart workmanlike manner, without dawdling. When the outside dressing has been removed the field of operation is surrounded with sterilised towels, the gauze removed, the wound soaked with biniodide lotion (1 in 2000), and tube removed, and the wound dusted with iodoform and a new dressing put on.

When the wound is dressed at a later period of its repair the same precautions are taken, lest by chance a part of it should not be healed. Moreover, the young reparative material does not seem very well able to resist infection, and sometimes breaks down again.

Evidences of Asepsis.

Most surgeons infer the asepticity of wounds from their clinical characters. Under some circumstances these may be relied upon, but in cases of doubt the tests which I have already described ought to be applied. The inoculation of culture media with fluid from the drainage-tube, with sutures, or with particles of epithelium, and so forth, is a delicate and reliable test.[1] I have learnt to look upon the slightest moisture,

[1] Von Nussbaum, "Leitfaden zur antiseptischen Wundbehandlung," Stuttgart, 1887, p. 15.

other than fresh blood or clear serum, as almost certain evidence of infection.

The examination of wounds by culture methods often affords unexpected results. A lumbar abscess connected with spinal caries was examined on several occasions. After a few dressings, by one who was careless, the pus contained *staphylococcus albus*, later it contained *albus* and *citrius*, and still later it contained a putrefactive bacillus.

To avoid such dangers psoas and lumbar abscesses are now emptied, irrigated, dusted with iodoform powder, or partially filled with iodoform emulsion, and then sewn up and dressed without any drainage. When this is done aseptically the worst that can happen is the re-accumulation of the pus.

As I have already pointed out, there are many kinds of pus. Tuberculous pus, such as is found in psoas and lumbar abscesses, contains a microbe, the tubercle bacillus, which is very slow in its effects upon the tissues, and does not easily enter the circulation. But it would be most dangerous to proceed in the same way when the pus contained *staphylococcus aureus* or *streptococcus pyogenes*.

The tubercular pus does not always re-accumulate. Some weeks ago I explored a boy's hip, and found the head of the femur carious, the joint full of pus, and an abscess in the gluteal region. The head of the femur

was removed, together with some of the acetabulum, and the joint and abscess easily cleaned out, irrigated, and rubbed with iodoform. The boy's temperature fell to normal, and nothing more was seen of the abscess.

Disinfection of Septic Wounds.

A septic sinus, ulcer, or fistula, is the most serious complication of an aseptic operation. Such wounds are infested by virulent bacteria, which are only kept out of the circulation by a layer of granulation tissue. If they get into a fresh wound they excite the most acute local inflammation, and may pass along the veins and lymphatics, and cause pyæmia or septicæmia. When the skin is unbroken, an amputation of the breast for malignant growth is a safe and successful operation. But when the growth has ulcerated, the mortality from septicæmia is very high. The only case of septicæmia which I have had occurred in a case of ulcerated carcinoma of the breast. When it occurred I had not realised the impotence of our antiseptics. Evidence was afterwards obtained which seemed to prove that the wound had been infected with bacilli from the cancerous ulcer.[1] Two other cases of the same kind happened within a short period.

[1] Hunterian Lectures on "Traumatic Infection," Edin. and Lond., 1895, p. 57.

The chemicals at our disposal for the disinfection of septic wounds and ulcers are, as I have endeavoured to show, exceedingly untrustworthy. I myself have always failed to disinfect septic sinuses or wounds when the result has been tested with culture media.[1] But of late much better results have been obtained by more determined efforts. I now endeavour to disinfect a septic sinus or ulcer by scraping with a Volkmann's spoon, washing at the same time with biniodide of mercury lotion—one part in one thousand—and thoroughly rubbing with pure carbolic acid, to which enough water or glycerine has been added to keep it liquid. This is finally washed away with more lotion. If possible, the operation is planned so as to avoid the sinus or ulcer, which is shut off with gauze soaked in iodoform collodion. If the sinus cannot be excised, it is thoroughly rubbed with iodoform and drained.

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[1] "Report on Aseptic and Septic Surgical Cases," *Brit. Med. Journ.*, London, 28th May 1892.

CHAPTER XIX.

RESULTS OF ASEPTIC SURGERY.

I HAVE already said that at first the aims of antiseptic surgery were not so high as they are now. But even in the beginning, chemicals did away with the worst kinds of sepsis, and wounds no longer stank. The most wonderful results were seen abroad. Pirogoff said those scourges of surgery, suppuration, purulent œdema, hospital gangrene, erysipelas, and tetanus, stalked *Schritt und Tritt* with surgery. Lindpainter wrote that hospital gangrene attacked eighty per cent. of the wounds in Von Nussbaum's wards. Erysipelas was the order of the day, and was looked upon as a normal sequence; a scalp wound was never sutured; in one year, eleven amputation cases out of seventeen died of pyæmia; in compound fracture purulent infection, hospital gangrene, and septicæmia ushered in a swift mortality.[1]

Von Nussbaum's own statements bear out those of his assistant.[2] Young and hearty people often

[1] Quoted from Schimmelbusch.

[2] "Leitfaden zur antiseptischen Wundbehandlung" 1887, 5th edition.

died after a trifling wound of pyæmia or hæmorrhage, following upon hospital gangrene. He says, that in 1846 Sédillot performed his first gastrostomy. The patient died of septic peritonitis. After Sédillot, the operation was done twenty-seven times with the same result, and surgeons gave up trying to solve the problem. How altered things are now! The peritoneum is now put to much severer trials than gastrostomy, and it is unnecessary to say how it emerges from the ordeal. I myself have not been called upon to treat secondary hæmorrhage after amputation since I was house surgeon in 1880.

The surroundings under which these things happened were such as we have never experienced. Reverdin[1] says that in 1877 Volkmann had a kind of photographic studio for an operation theatre, and wretched barracks for wards. Proper sanitary appliances were wanting, and such as might be, were actually within the wards. Volkmann himself compared them to public latrines. Yet he claimed that after he began to use antiseptics he obtained excellent results.

Von Nussbaum says that surgical therapeutics have improved so much that in the Italian war of 1859 he saw a great deal of hospital gangrene, little in

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[1] "Antisepsie et Asepsie chirurgicales."

the Bohemian war of 1866, and none in the German war of 1870. Antiseptics had quite mastered it.[1]

It is probable that in British hospitals the infective diseases were never so prevalent as they were abroad. Better sanitation, better nursing, and better food, and a higher standard of personal cleanliness kept them at arm's length. Suppuration, however, was looked upon as an ordinary occurrence, and was attended by its handmaids, erysipelas, pyæmia, and septicæmia.

Before Sir Joseph Lister used antiseptics (1864 and 1866) he lost sixteen major amputations out of thirty-five (45·7 per cent.). Afterwards (1867, 1868, 1869), he lost six out of forty (15 per cent.).[2]

At a later period Sir Joseph Lister performed eighty major amputations with nine deaths (11·25 per cent.). Mr. Spence did ninety-seven major amputations with a mortality of twenty-five (25·7 per cent.). These surgeons were working in the same hospital and under the same conditions, except that one used antiseptic methods and the other did not.

Last year (1894) 4219 surgical cases were treated in the wards of St. Bartholomew's Hospital,[3] and 1743

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[1] *Loc. cit.*, p. 30.

[2] Cheyne, "Antiseptic Surgery," p. 368, *et seq.*

[3] *See* "Surgical Statistics," *St. Barth. Hosp. Rep.*, London.

operations were performed, a vast number of minor operations being also done in the various out-patient departments. Six of those who were operated upon had erysipelas afterwards, but none of them died. Pyæmia occurred twice, and both patients died. Septicæmia also occurred twice after operations done for fungating cancer of the breast. Cases such as this are not, as I have pointed out, the same as those in which there is no sepsis before the operation. An ulcer, a sinus, a suppurating sore, are most dangerous complications.

Reverdin[1] says that abroad they formerly lost 90 per cent. of cases of amputation through the thigh. In ten years (1884 to 1893) 156 amputations of the thigh were done in St. Bartholomew's Hospital for disease. Twenty-one of these cases died, giving a mortality of 13·4 per cent. In the previous ten years (1874 to 1883) 192 amputations were performed through the thigh, with a mortality of twenty-nine, or 15·10 per cent. Amputations are becoming less frequent and less dangerous.

But statistics such as these give no idea of the saving of pain or of the lessened stay in the hospital. The patients, too, appreciate the new order, and seldom shrink when an operation is advised.

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[1] *Loc. cit.*, p. 243.

I have said that our hospital statistics do not record cases of suppuration; but within my own recollection, the improvement in this respect has been very striking. Some time since I published a series of operations for the radical cure of hernia;[1] out of forty-four recoveries after the radical cure of non-strangulated hernia done at the Great Northern, St. Bartholomew's, and elsewhere, thirty-six healed by first intention. Of this number thirty required a single dressing and five required two, and one, a troublesome schoolboy, required several. Of the remaining eight cases five had suppuration, which ended in the extrusion of some or all of the deep sutures; and three had very slight suppuration, which made no appreciable difference in their healing. Since this the suppuration has been less, although the operations have been of a severer kind, so that of sixty-one cases which recovered after radical cure of non-strangulated hernia five had slight suppuration. Three of these cases occurred under house surgeons who had never prepared a case for me before. Fifty-two out of the fifty-five which healed by first intention had but a single dressing; that is to say, when the wound was dressed on the eighth day it was healed, and only needed to be protected with a little gauze or wool and a bandage. Radical cure was also done five

[1] *Lancet*, 25th November 1893.

times after the operation of kelotomy. All healed by first intention. Two were drained and required several dressings.

We consider the operation of radical cure to be one of the severest tests of aseptic surgery. In each wound a number of silk sutures are buried, and the operation is prolonged, and accompanied with a good deal of manipulation. Moreover, the region is one which is hard to disinfect and keep aseptic.

The radical cure of hydrocele by excision of the parietal tunica vaginalis is a somewhat similar operation, but requires much less manipulation, and no sutures are left buried in the wound. One out of twenty-six cases of excision of the parietal tunica vaginalis for the radical cure of hydrocele and of hæmatocele suppurated slightly, and in that the suppuration was due to several escapes of urine into the dressings.

In the operation for the cure of varicose veins the conditions are also favourable to suppuration. During the last two years I have notes of twelve cases. In most of these both legs were operated upon, and one had thirty-one incisions. Some of the incisions suppurated slightly in one case. Those who have read Sir Benjamin Brodie's lectures will remember the horrible calamities which used to follow these operations, and which led him to give them up. Indeed, this and many other

operations would not be justifiable unless we could promise security from infection. But we cannot yet promise, I regret to say, an absolute security.

When suppuration follows an operation done with aseptic precautions it is seldom or never of a severe type. Sloughing and phagedæna do not accompany it, and the patient seldom becomes ill.

In many of the cases which heal by first intention bacteria are present when the dressing is taken off on the eighth day. This is easily ascertained by inoculating culture media with sutures or anything from the wound. With the help of Mr. Maxwell and others I have repeatedly tested wounds with culture media. Our experiments are not numerous, but we estimate that half the cases are sterile. From the infected cases we have almost invariably grown skin bacteria, *staphylococcus epidermidis albus* and *bacillus epidermidis.* It is probable that these emerged from the sweat glands, or sebaceous glands, or the hair follicles after the wound had healed too far for them to do any harm. Moreover, these bacteria belong to kinds which are not particulary pathogenic. Their presence, however, is undesirable. Our aim is sterility. Methods which allow the presence of one kind cannot be relied upon with absolute certainty to exclude another. More information is needed as to the presence or absence of bacteria from wounds treated by

aseptic methods. Many surgeons now-a-days claim to practice aseptic surgery, but hardly any have told us how far their attempts have been crowned with success.

There is a profound gulf betwixt the statements "the wound healed well" and "the wound was sterile." It is strange that such simple and scientific tests as culture media are not oftener used.

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